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NUMBER 2

THE LAKE TROUT OF SWAN LAKE, ALBERTA

Alberta
Dept. of
RECREATION, PARKS
AND WILDLIFE

THE LAKE TROUT (*Salvelinus namaycush*),
OF SWAN LAKE, ALBERTA

by

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ABSTRACT

Swan Lake, Alberta, is a small mesotrophic lake containing a population of lake trout *(Salvelinus namaycush)* and pike *(Esox lucius)*.

The diet of the lake trout consists primarily of *Chaoborus* larvae and *Gammarus*. Growth is rapid except in older age classes. The trout mature at age VI and few over age IX are found.

Comparative studies of some meristic characters suggest that there may be adaptive selection associated with the unusual diet of this population.

Spawning takes place in a short section of outlet stream. Egg deposition appeared to be affected by water depth but not by stream flow. Hatching extends over a period of about four months.

A tagging study indicated a total adult population of about 200 fish. Anglers captured 34 per cent of these fish in a period of 18 months.

ACKNOWLEDGEMENTS

My thanks are due to many people for their assistance in this study. J. Folinsbee operated the creel census station in 1965 and D. Severson in 1966 and 1967. The latter, in particular, provided valuable assistance in the collection and analysis of field data. I am indebted to C. W. Hunt, who provided valuable field assistance and advice. W. E. Willows and other personnel of the Alberta Department of Lands and Forests provided assistance on various occasions.

Mr. M. Pinsent identified the zooplankton and Mr. K-Lin Chang the phytoplankton; Mr. A. Nimmo identified many immature insects and Miss J. Anderson the species of *Chaoborus*. Mr. Nigel Martin read a number of lake trout scales. Dr. Saul Zalik provided advice on the statistical analysis of the data. To these people I express my sincere thanks.

My thanks are due to Dr. J. R. Nursall for his supervision of the study and criticism of the manuscript. I am also indebted to Mr. M. E. Riske, Dr. D. D. Beatty and Dr. R. J. McNab for their criticism of the manuscript. The constructive criticism of Dr. S. B. Smith and M. J. Paetz has also been appreciated.

I am indebted to the Alberta Department of Lands and Forests for financial aid in 1963-64 and for permission to spend many working hours collecting data for the study.

To my wife, Anne, I am particularly grateful for her patience, understanding and encouragement.

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Mr. H. Pinsent identified the zooplankton and Mr. A-Lan Chang the phytoplankton; Mr. A. Simon identified many immature insects and Miss J. Anderson the species of chironomids. Mr. Nigel Martin read a number of fish scale samples. Dr. Neal Baltz provided advice on the statistical analysis of the data. To these people I express my sincere thanks.

My thanks are due to Dr. J. R. Nursall for his supervision of the study and criticism of the manuscript. I am also indebted to Mr. H. L. Evans, Dr. D. D. Lawson and Dr. R. C. Gooch for their criticism of the manuscript. The constructive criticism of Dr. C. H. Smith and H. J. Harris has also been appreciated.

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I. INTRODUCTION

Preliminary observations made at Swan Lake in western Alberta during the course of fishery management investigations for the Fish and Wildlife Division, Alberta Department of Lands and Forests, indicated that this lake possessed several interesting features (Cunningham, unpublished). Samples of the fish population showed that pike (*Esox lucius* Linnaeus) and lake trout (*Salvelinus namaycush* Walbaum) were the major fish species inhabiting the lake. Temperature and dissolved oxygen observations suggested that conditions in late summer might restrict the amount of habitat available to the lake trout. Reports from Fish and Wildlife officers and local residents indicated that at least a portion of the lake trout population entered the outlet stream to spawn.

Access to Swan Lake had been improved markedly in the few years prior to the study and angling pressure had increased significantly. A decrease in the number of larger lake trout taken by angling was reported.

The purpose of this study was twofold. Firstly, it was to investigate the ecology of the lake trout in this lake. Some emphasis in the study has been placed upon feeding and spawning habits, as these aspects appeared to be of particular interest. Secondly, it was to evaluate the effect of angling pressure upon this population of fish. Data have been collected to provide the basis for a management programme for the species in this lake. As a result of the restricted access to the lake, it was possible to collect complete data on angling success during the open water season. The assistance of anglers was also obtained in the collection of biological data for the study.

II. MATERIALS AND METHODS

1. Organization

Collection of data for this study began in September, 1964 and terminated in June, 1967. A field station was established at the lake in June, 1965 and was operated continuously during the following periods:

5 June - 15 October, 1965

6 May - 13 October, 1966

17 May - 16 June, 1967

Sampling was carried out in winter on occasional visits to the lake. Some additional samples were submitted by anglers.

Three limnological stations were established at locations shown in Figure 6. All regular measurements of temperature, dissolved oxygen and transparency were made at these stations, as also were plankton collections. The lake was divided into numbered areas and bottom fauna samples were collected from these on a random basis.

Data on angling success were collected by personal interview with anglers in summer and from voluntary creel cards in winter. Many of the data on the fish were taken from specimens caught by anglers, supplemented by other specimens taken by gill net, trap net and trammel net.

2. Limnology

(a) Physico-chemical

A Bendix DR-19 marine depth recorder was used to sound Swan Lake. Soundings were plotted on a lake outline traced from an Alberta Department of Lands and Forests aerial photograph and a contour map constructed (Figure 6). Parameters of lake morphometry were calculated as outlined by Welch (1948). Area was calculated by the "cross-section

paper" method. In this method a contour map is drawn on squared paper and the number of squares and part-squares within each contour interval counted.

Lake water temperatures were measured using a Whitney thermistor-thermometer. A Ryan submersible 7-day recording thermometer was used to record stream temperature in the outlet prior to September 19, 1965, and subsequently in the inlet. After September 19, 1965 and during 1966 a Negretti-Zambra 7-day recording thermometer was used to record outlet temperatures. Each of these instruments was standardized against a mercury thermometer calibrated to 0.1C.

Stream flow observations were made using both the 'float method' outlined by Welch (1948), a Gurley pgymy-type current meter, and a 'head rod'.

Water samples for physical and chemical analysis were obtained using a 1200 ml Kemmerer sampler. Dissolved oxygen content was determinted by the Miller (1914) method. Chemical analyses were carried out by the Alberta Provincial Analyst.

The transparency of the lake water was measured with a Secchi disc 20 cm in diameter. Measurements were made whenever other limnological measurements were being made and the light conditions at the time were noted.

A Hellige pocket comparator was used for the determination of pH. The comparator was fitted with a bromthymol blue-B colour disc (range pH 6.0 - 7.6) and a cresol red-B colour disc (range pH 7.2 - 8.8).

The substrate was examined by means of a six-inch square Ekman dredge. Two SCUBA divers of the Alberta SCUBA Divers Council also surveyed the lake bottom to determine differences in the substrate and

searched for rocky areas which might attract spawning trout.

(b) Biological

Plankton samples were collected using a 'Wisconsin' style net with a diameter of 25 cm. and fitted with No. 20 bolting silk. All samples were from 20-foot vertical hauls taken at one of the three sampling stations. Samples were preserved in 10 per cent A.F.A. solution for subsequent analysis.

Bottom fauna samples were collected with a six-inch square Ekman dredge. Prior to July 1, 1965 samples were from an area of 0.25 square feet. Subsequently all samples were a composite of four individual samples, representing a total area of one square foot. Samples were washed with lake water through a brass mesh screen consisting of 35 meshes per inch. The organisms were picked, separated into jars and preserved in 10 per cent formalin. They were later identified, counted, and had their displaced volumes measured.

3. Fish

(a) Collection of Specimens

A substantial number of samples and measurements were taken from fish caught by anglers. Various other methods were also used to collect additional specimens.

Gill nets eight feet deep and 50 yards long, with mesh sizes from one and one half inch to five and one half inch stretched mesh, were used for the collection of specimens and for the collection of live specimens for tagging in May and June of 1966. Sets for the former were overnight, while for the latter the nets were checked at two to three hour intervals. Fifty-foot monofilament nylon nets eight feet deep,

with mesh sizes of 19 and 33 mm stretched measure, were also used for sampling small fish.

A trap net with a six foot square box was used for a period of about two months in 1966, with little success.

A trammel net 100 yards long and consisting of two sheets of 20-inch mesh net and one of two-inch mesh net was used primarily for live trapping, but also in the collection of small lake trout and pike. It proved to be particularly valuable in checking prespawners for sexual condition.

In September, 1965 a fence was built across the outlet creek using a heavy-gauge rectangular-mesh screen and steel fence posts. Two fish traps were incorporated into this fence, one facing in each direction, to capture fish moving up- and downstream. The traps had funnel-shaped entrances constructed of one-inch chicken wire. This arrangement did not prove to be effective for monitoring fish movements and was subsequently abandoned in favour of the use of short sections of four-inch mesh gill net four feet in depth, set across approximately two thirds of the width of the creek. This sytem permitted only partial sampling of the spawning fish but complete sampling did not prove feasible with the equipment and manpower available.

Fish collections in the outlet creek were made using a fish shocking unit, powered by a 230 volt DC Homelite generator.

(b) Tags

In the population study numbered FT-6 dart tags manufactured by Floy Tag and Manufacturing Inc., of Seattle were used.

The tags were inserted one quarter to one half-inch to the left of the dorsal fin and forced between the interneurals. An applicator

needle was not used but an incision was made prior to insertion, using a number 16 hypodermic needle. Instruments and tags were dipped in 70 per cent alcohol before use.

(c) Measurements

All lengths of fishes are fork lengths measured to the nearest millimeter.

Head lengths were measured from the tip of the snout to the farthest point of the operculum, using Mauser calipers and measuring to the nearest 0.1 millimeters. Maxilla length was similarly measured from the tip of the snout to the posterior tip of the maxilla.

Fish were weighed on a Mikro field balance, generally to the nearest 10 grams.

Lateral line scale counts were made by counting the number of sensory pores, as opposed to counting the number of oblique rows of scales. Differences in the two methods were noted by Rounsefell (1963). This method was selected as it was considered an easier and more reliable one under field conditions.

Fish were aged by the scale method. Scale impressions were made on cellulose acetate slides and the impressions examined under a Bausch and Lomb Tri-Simplex Microprojector.

All gill raker counts were made on the left first branchial arch. Counts were made separately on the upper and lower arms of the arch. The longest gill raker was cut from the arch and then measured with Mauser calipers to the nearest 0.01 millimeters. This raker was consistently found at the same location on the gill arch in all the specimens examined.

Pyloric caecum counts were carried out following preservation

of the tissue in 30 to 40 per cent formalin until the caeca were relatively stiff. Counts were made by removing the caeca one by one from the gut wall.

The contents of fish stomachs were squeezed into vials and preserved in 10 per cent formalin for subsequent examination. The contents of each stomach were separated according to taxonomic groups and the volume displacement of each group measured, after drying the specimens on absorbent paper. Numbers of individual organisms were either counted or estimated by counting a representative sample and extrapolating. Identification was carried to the genus or species level where possible.

III. PAST STUDIES

Limited investigations have been carried out on Swan Lake prior to this study period but none of the work has been published.

A preliminary lake survey carried out in 1959 was reported by Cunningham (1960, unpublished). Fish sampling was carried out and limnological observations were also made, both in 1960 and 1963, as part of the management studies for the Fish and Wildlife Division, Department of Lands and Forests.

IV. DESCRIPTION OF THE STUDY AREA

1. Geographic location and general description of drainage basin

Swan Lake is situated at longitude 115° 10'E. and latitude 52° 07'N. It lies approximately 25 miles (40 km) south-west of Rocky Mountain House, Alberta, and is situated within the Clearwater Forest Reserve about one mile (1.6 km) from its eastern boundary.

The lake lies at an altitude of 3,950 feet above sea level. It is both fed and drained by Swan Creek, a tributary of Prairie Creek, the latter a tributary of the upper North Saskatchewan River drainage (Figure 1). The lake is fed by a drainage basin approximately 31 square miles ($80.3\ km^2$) in area (Figure 2).

Swan Lake is readily accessible to the public by an all-weather gravelled forestry road which approaches from the west. A campsite has been established at the lake and is extensively used during the summer months, primarily by anglers. Prior to the construction of the forestry road in 1959 access was by means of a variety of trails and restricted during adverse conditions. Consequently, angling pressure at Swan Lake has varied over a period of years, but there has been some degree of fishing at the lake over the past thirty-five to fifty years.

2. Soils

The soil types of the Rocky Mountain House area are described and mapped by Peters and Bowser (1960). The soil of the Swan Lake area is podsolic grey-wooded, low in fertility and organic matter.

Because of leaching in the upper horizons the subsoil is often richer in mineral nutrients than is the surface soil. Several outcroppings of glacial till are to be found around the lakeshore.

3. Climate

The climate of the region is characterized by moderately warm summers and relatively cold winters. The mean summer temperature at Rocky Mountain House is 50F and mean annual precipitation is 19.09 inches (Peters and Bowser, 1960).

Rocky Mountain House is the nearest weather station with continuous records from 1950-67. Figure 3 shows mean temperatures for the months of May to October in 1965 and 1966 at both Clearwater Ranger Station and Rocky Mountain House and also the long term averages at Rocky Mountain House. Figure 4 shows similar data for precipitation. In Figure 5 the precipitation data for the Clearwater Ranger Station are broken down into five day periods.

Clearwater Ranger Station is situated eight miles (12.8 km) south of Swan Lake and is subject to very similar weather conditions. Temperatures at this location are, on average, cooler during the summer than at Rocky Mountain House and the area receives more precipitation.

Temperatures in the summer of 1965 were almost consistently lower than average and precipitation was higher. In 1966 temperatures were slightly below average and precipitation close to normal, with the exception of certain rainfalls in July and August.

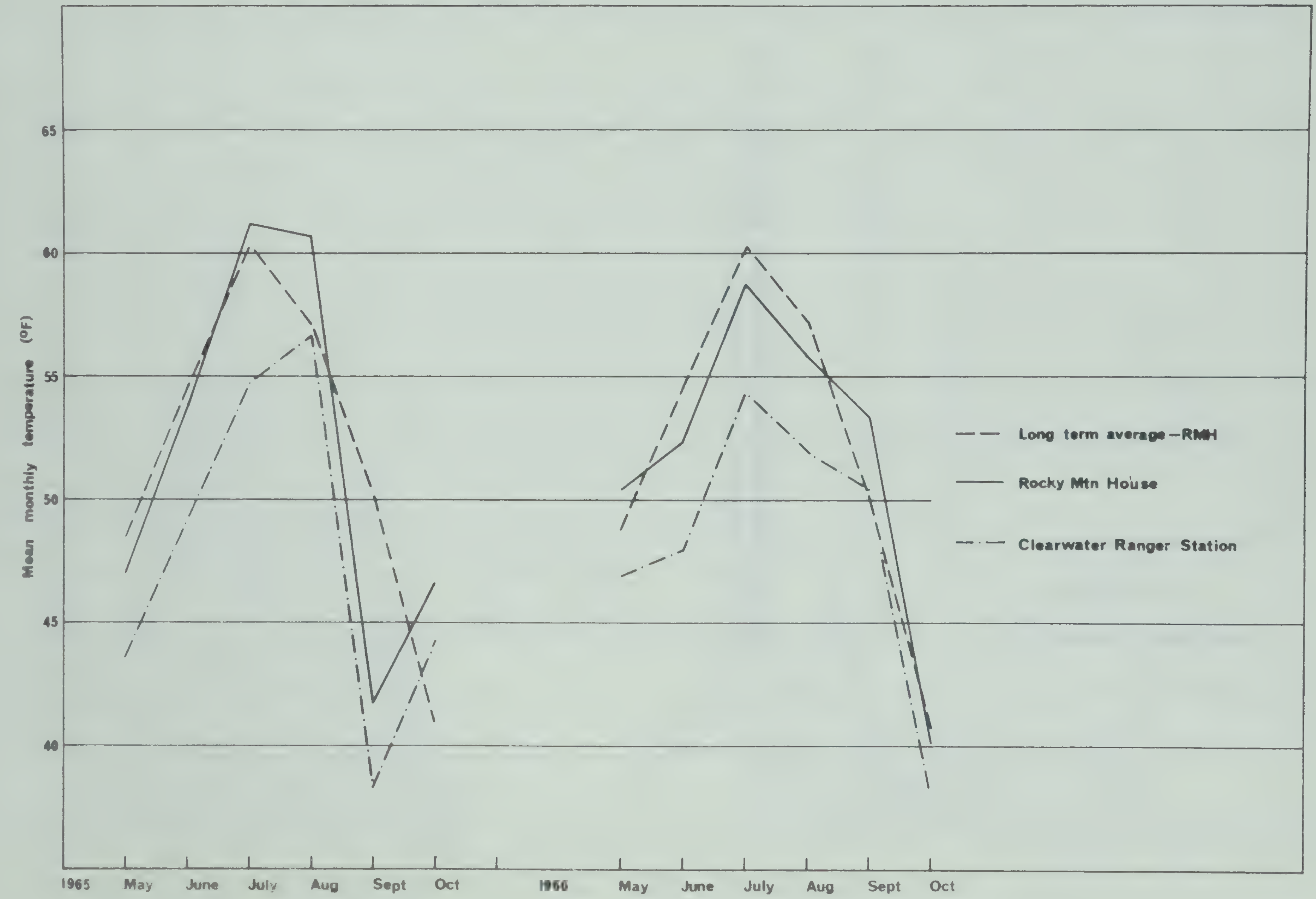
Figure 1. Geographic location of Swan Lake, Alberta.


N
EDMONTON
RIVER
SASKATCHEWAN
NORTH
Brazeau
River
Ram
River
Prairie
Cr.
Swan
Cr.
River
Clearwater
SWAN LAKE
Medicine
River
RED DEER
RIVER
DEER
RED
16 miles
25 km

Figure 2. Location of Swan Lake in relation to its immediate drainage basin.


N
Campsite
SWAN LAKE
SWAN CR.
SWAN CR.
1 mile
1 km
Marshy Area
Access Road

Figure 3. Mean monthly temperature in Swan Lake area, 1965 and 1966, compared with long-time means.



Mean monthly temperature (°F)
65
60
55
50
45
40
1965
May
June
July
Aug
Sept
Oct
1966
May
June
July
Aug
Sept
Oct
Long term average – RMH
Rocky Mtn House
Clearwater Ranger Station

Figure 4. Mean monthly precipitation in Swan Lake area, 1965 and 1966, compared with long-time means.

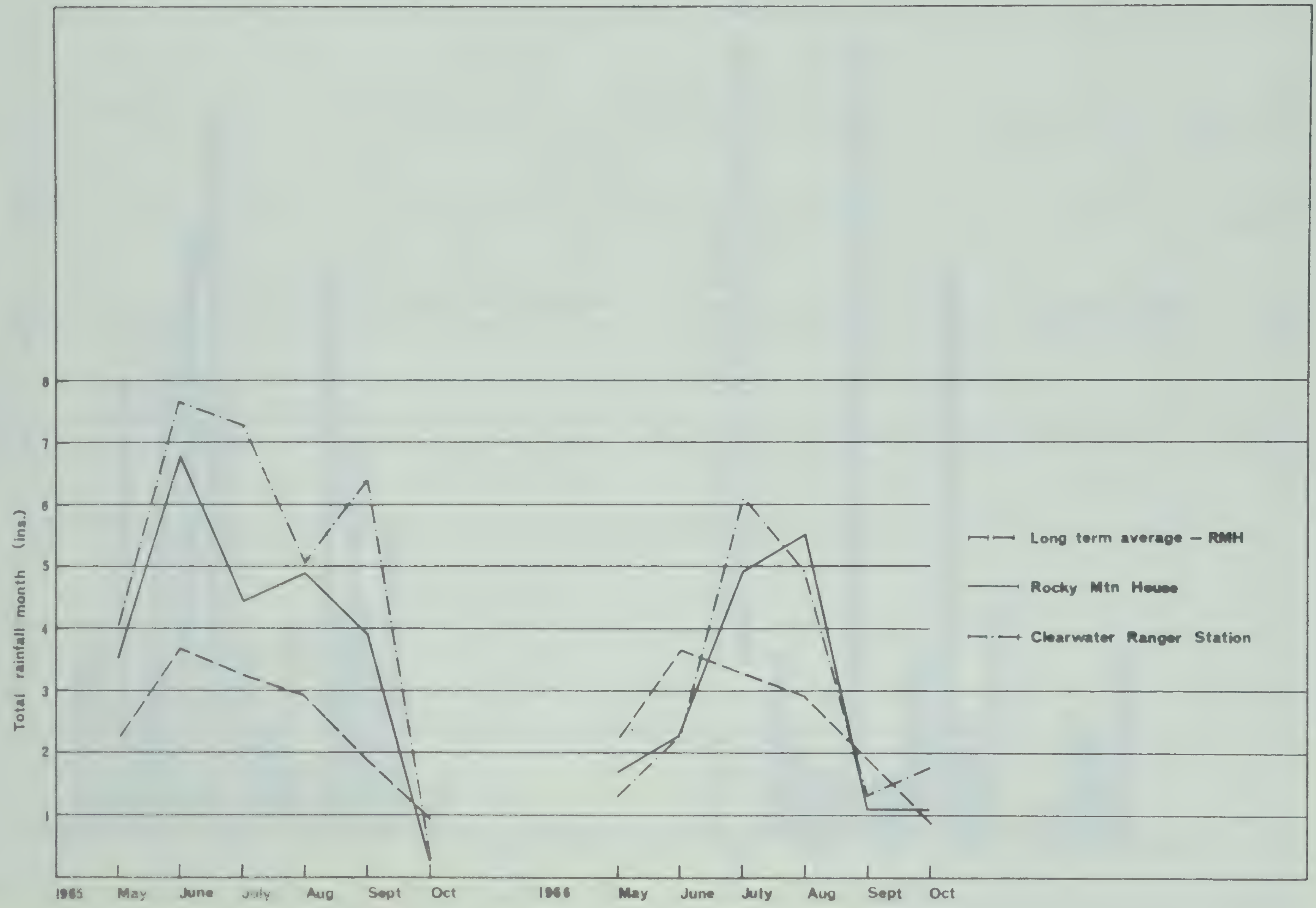
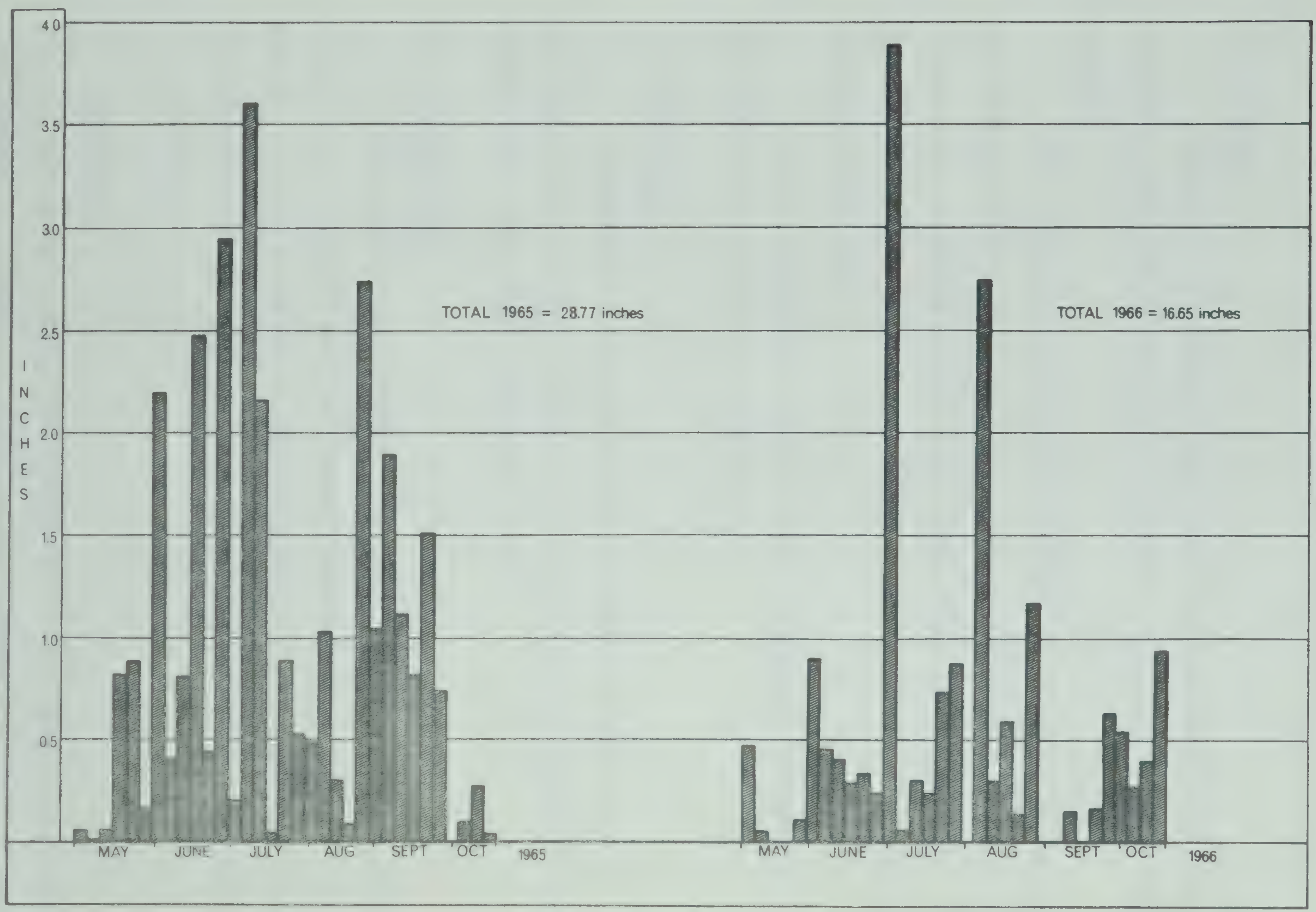

Total rainfall month (ins.)
8
7
6
5
4
3
2
1
1965
May
June
July
Aug
Sept
Oct
1966
May
June
July
Aug
Sept
Oct
Long term average – RMH
Rocky Mtn House
Clearwater Ranger Station

Figure 5. Summer precipitation at Clearwater Ranger Station, 1965 and 1966, plotted in five-day periods.



INCHES
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
TOTAL 1965 = 28.77 inches
TOTAL 1966 = 16.65 inches
MAY
JUNE
JULY
AUG
SEPT
OCT
1965
MAY
JUNE
JULY
AUG
SEPT
OCT
1966

V. PHYSICAL AND CHEMICAL CHARACTERISTICS

1. Drainage

Owing to the relatively small area of the drainage basin which feeds Swan Lake, stream flows into the lake are closely correlated with rainfall.

Flow readings in the outlet were taken at irregular intervals. Six readings yielded an average flow of 28.4 c.f.s., ranging from a low of 5.9 c.f.s. to a high of 76.9 c.f.s. High flows in 1965 probably exceeded 100 c.f.s.; the low flow recorded is probably very close to the winter base flow.

With an average flow of 28.4 c.f.s., a complete exchange of lake water would take place every 177 days.

2. Morphometry

Morphometric data for Swan Lake are shown in Table I and a bathymetric map is given in Figure 6. The lake basin is generally saucer-shaped, with a relatively flat central area.

3. Wind exposure

Swan Lake lies on an East - West axis. Hills around the north, south and east shores block wind access from these directions. To the west of the lake the valley is broad and relatively flat and wind access is good. As a result, most of the effective wind action is from a westerly direction.

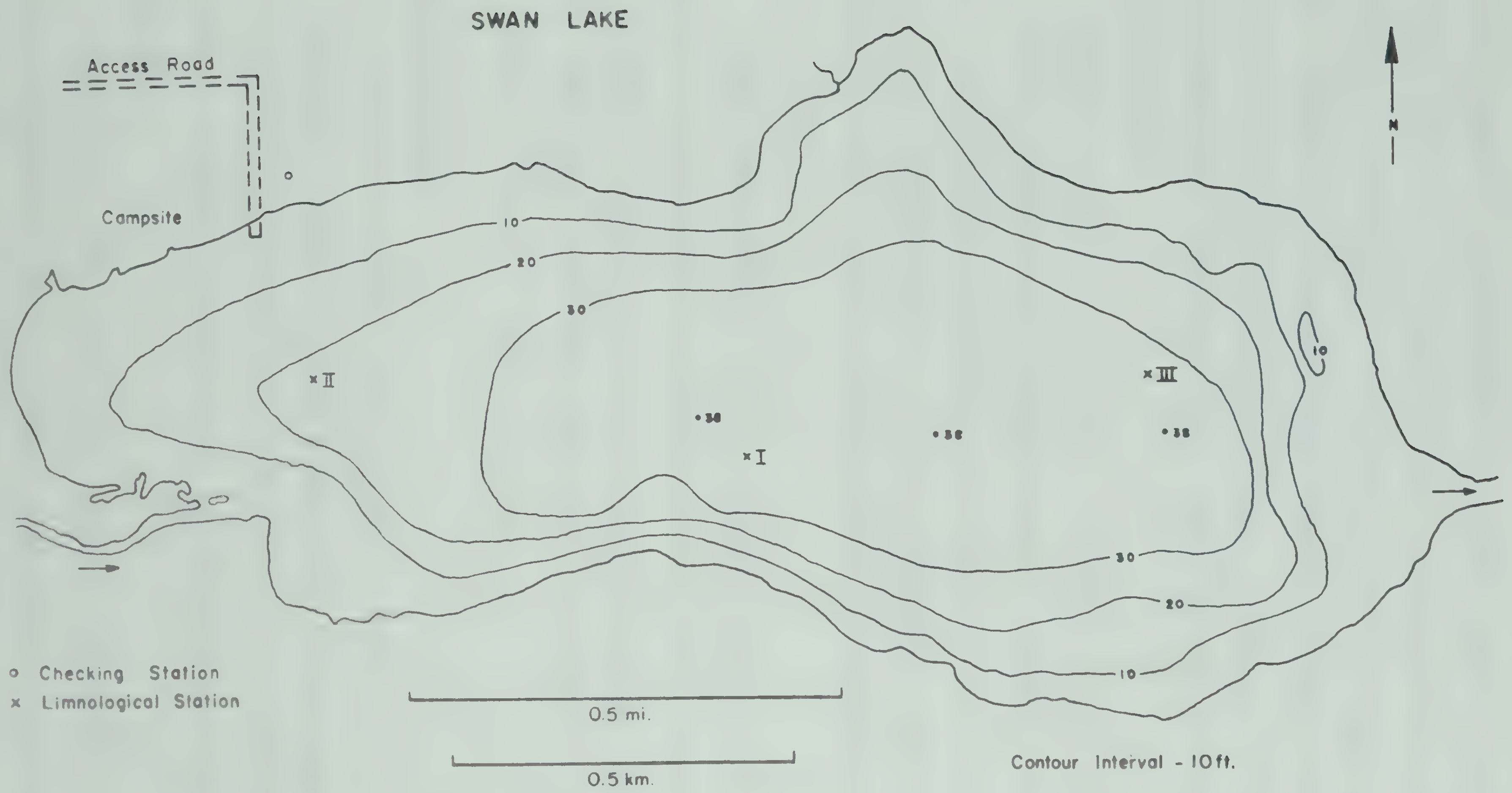
4. Transparency

Secchi disc readings were taken at all three limnological stations (Figure 6). Station I, being the most centrally located and least

TABLE I. Morphometric parameters of Swan Lake

PARAMETER		
Surface area	1.97 sq km	(493 acres)
Volume	12.2 $m^3 \times 10^6$	(9,978 acre feet)
Maximum depth (Z_m)	11.6 m	(38 feet)
Mean depth ($\overline{Z}$)	6.16 m	(20.2 feet)
Maximum length	2.57 km	(1.60 miles)
Maximum width	1.18 km	(0.73 miles)
Shoreline length	7.07 km	(4.33 miles)
Shoreline development	1.39	
$\overline{Z}/Z_m$	0.53	
Percentage of lake area less than 10 ft. (3.05 m) deep 30.45		
Percentage of lake area 10 to 20 ft. (3.05 - 6.10 m) deep 18.50		
Percentage of lake area 20 to 30 ft. (6.10 - 9.15 m) deep 19.45		
Percentage of lake area over 30 ft. (9.15 m) deep 31.60		

Figure 6. Bathymetric map of Swan Lake, Alberta. Depths are shown in feet.


SWAN LAKE
Access Road
Campsite
N
10
20
30
10
20
30
× II
× I
× III
• 38
• 38
• 38
10
o Checking Station
× Limnological Station
0.5 mi.
0.5 km.
Contour Interval - 10 ft.

affected by changes in wind and stream flow, was therefore taken to be the most representative of lake conditions. Readings taken at this station are plotted in Figure 7. Exceptionally low readings at Station II generally reflect silt loads entering the lake from the inlet following heavy rainfall. Low readings at Station III were caused by the accumulation of plankton at this end of the lake following sustained wind action.

The mean of six readings taken at Station I in 1965 was 11.0 feet (3.35 m). The mean of 20 readings taken in 1966 was 14.5 feet (4.42 m). The mean of all readings taken at Station I is 13.7 feet (4.18 m). Lower average readings in 1965 resulted from heavy silt loads carried into the lake by above average rainfall and subsequent above average stream flows.

Secchi disc readings are not an actual measure of light penetration but a useful index of visibility (Welch, 1948). In this small lake readings are affected by both physical and biological factors. They are, therefore, used in this context only as an indicator, rather than a measure, of the level of productivity.

5. Water Chemistry

Analyses of the lake water are given in Table II.

Northcote and Larkin (1956) demonstrated the importance of total dissolved solids concentration as an indicator of lake productivity. A mean level of 250 ppm is indicative of a moderately high level of productivity.

Variations in the ignition loss indicate differences in the proportion of organic materials present, a reflection of the water exchange

Figure 7. Secchi disc readings at Station I, 1965 and 1966.

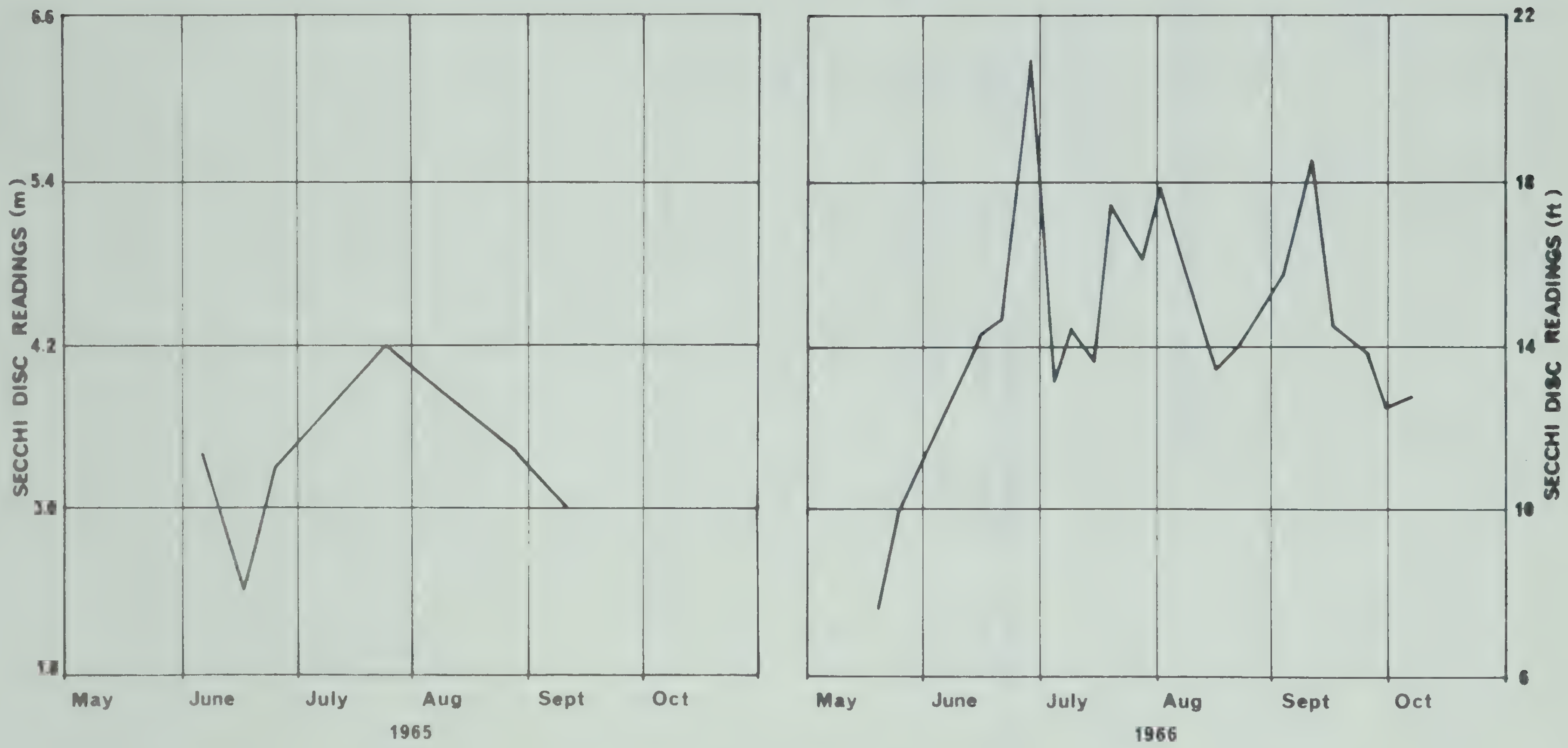

SECCHI DISC READINGS (m)
6.6
5.4
4.2
3.0
1.8
May
June
July
Aug
Sept
Oct
1965
SECCHI DISC READINGS (ft)
22
18
14
10
6
May
June
July
Aug
Sept
Oct
1966

Table II. Analyses of lake water, Swan Lake

Date	Total Dissolved Solids (ppm)	Ignition Loss (ppm)	Hardness (ppm)	Sulphates (ppm)	Chlorides (ppm)	Alkalinity (ppm)
24 Aug. 1959	268	108	110	26	-	160
1 Mar. 1965	254	106	170	4	8	200
5 Oct. 1965	216	72	140	18	-	170
14 Oct. 1966	262	42	180	47	2	210

rate. pH tests carried out on these samples and on other occasions indicate a range of 7.5 - 7.9.

6. Temperature

Ice covers the lake for a period of between five and six months. The lake was clear of ice on 10 May, 1966, but in 1967 a late spring maintained ice cover until 23 May. Freeze-up is reported to take place about the third week in November. On 10 November 1964 a thin ice cover extended about 300 feet (91 m) from shore. It is known, however, that in many years vehicles are driven on the ice early in December, an indication that at least six inches (15.2 cm) of ice is present at this time.

The thermal behavior of the lake during the periods June to October 1965 and May to October 1966 is shown in Figure 8. The high rainfall and resultant high water exchange rate in 1965 maintained significantly lower water temperatures in the lake during that year. It is evident, however, that the surface waters react readily to periods of warmer weather and thermal stratification is soon established. This stratification was found to break down readily under moderate wind action.

In 1966 average water temperatures in the lake were higher than in 1965. The 14C contour stabilized close to 15 ft (4.6 m), a level which averaged about 12C in 1965. The surface waters did not show substantial warming at any time and no marked thermal stratification developed during the summer. Temperatures remained high until the middle of September, although in 1965 cooling had begun at the end of August. The period of overturn appears to extend from mid- to late September until early November.

Figure 8. Seasonal temperature distribution (deg C) with depth in Swan Lake, 1965 and 1966.

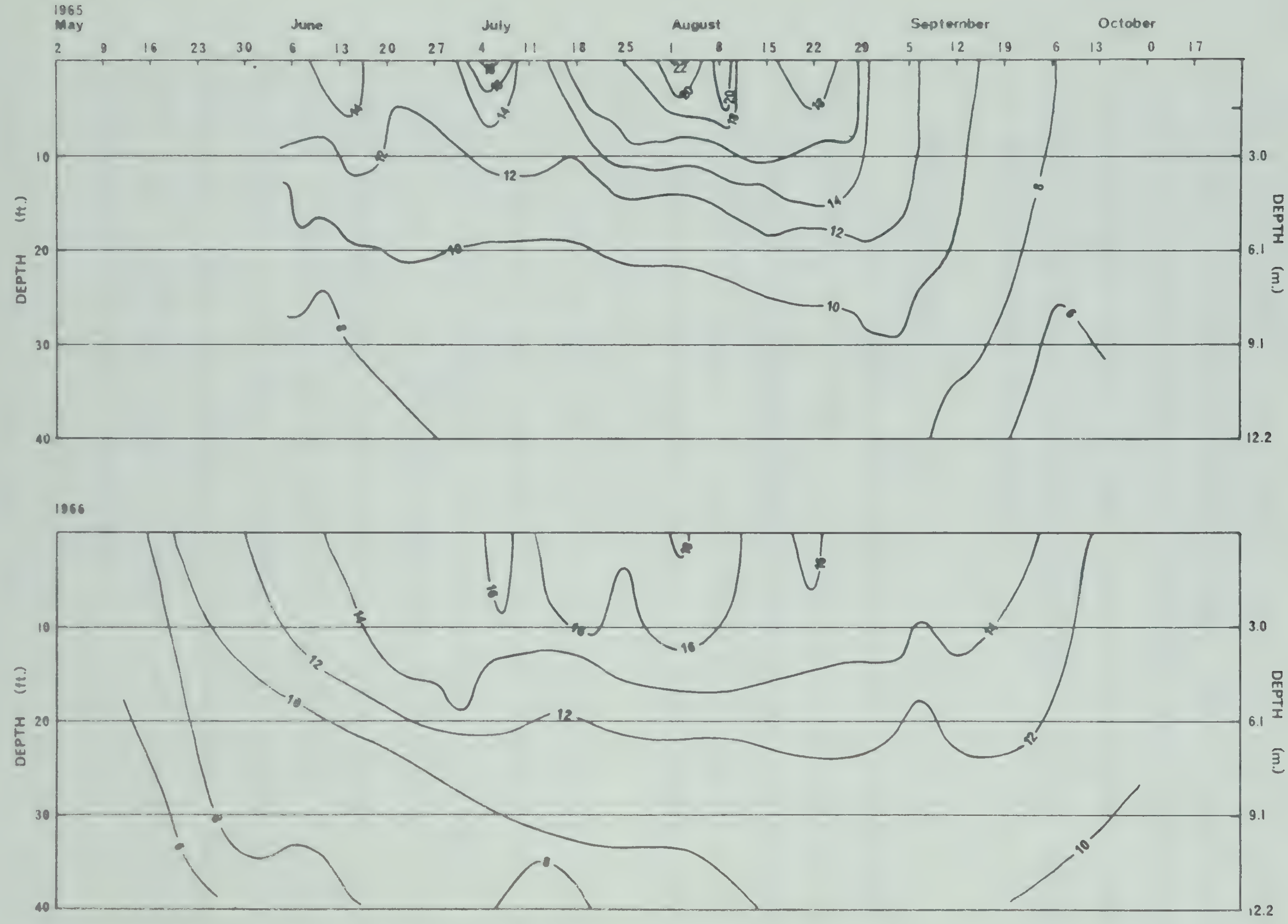

1965
May
June
July
August
September
October
2
9
16
23
30
6
13
20
27
4
11
18
25
1
8
15
22
29
5
12
19
6
13
0
17
DEPTH (ft.)
10
20
30
40
DEPTH (m.)
3.0
6.1
9.1
12.2
1966

Figure 9 shows the daily means of temperatures recorded in the outlet creek in 1965 and 1966. These readings are closely correlated with those of the surface waters of the lake. While no readings were taken during the period May to July 1965 higher values were recorded in August than at any time in 1966. Cooling took place very rapidly in early September 1965 and the creek remained cool. In 1966 cooling in the fall was very much more gradual.

7. Dissolved oxygen

The fall overturn occurs during a period of five to seven weeks during September and October, when westerly winds are generally prevalent. As a result dissolved oxygen levels are high in early winter and remain relatively high throughout the period of ice cover. Levels of 50 to 60 per cent saturation generally persist to a depth of 20 feet (6.1 m), even in late winter.

Figure 10 shows the dissolved oxygen conditions in Swan Lake during the periods June to October 1965 and May to October 1966. Based on several years' observations, the surface waters, to a depth of 15 to 20 feet (4.6 - 6.1 m), generally remain close to saturation, but in late summer oxygen depletion at greater depths may occur and can lead to a fairly sharp oxycline, such as that in the period August 26 to 30, 1965. The breakdown of this condition in 1965 was marked by below normal air temperatures, heavy rain and snowfall in early September. The rapid cooling and accompanying winds soon induced a water circulation, as illustrated by the oxygen concentration.

In 1966 conditions were more stable and less oxygen depletion was noted. The cooling of the lake waters in fall was more gradual.

Figure 9. Mean daily temperature in lower Swan Creek, Alberta, 1965 and 1966.

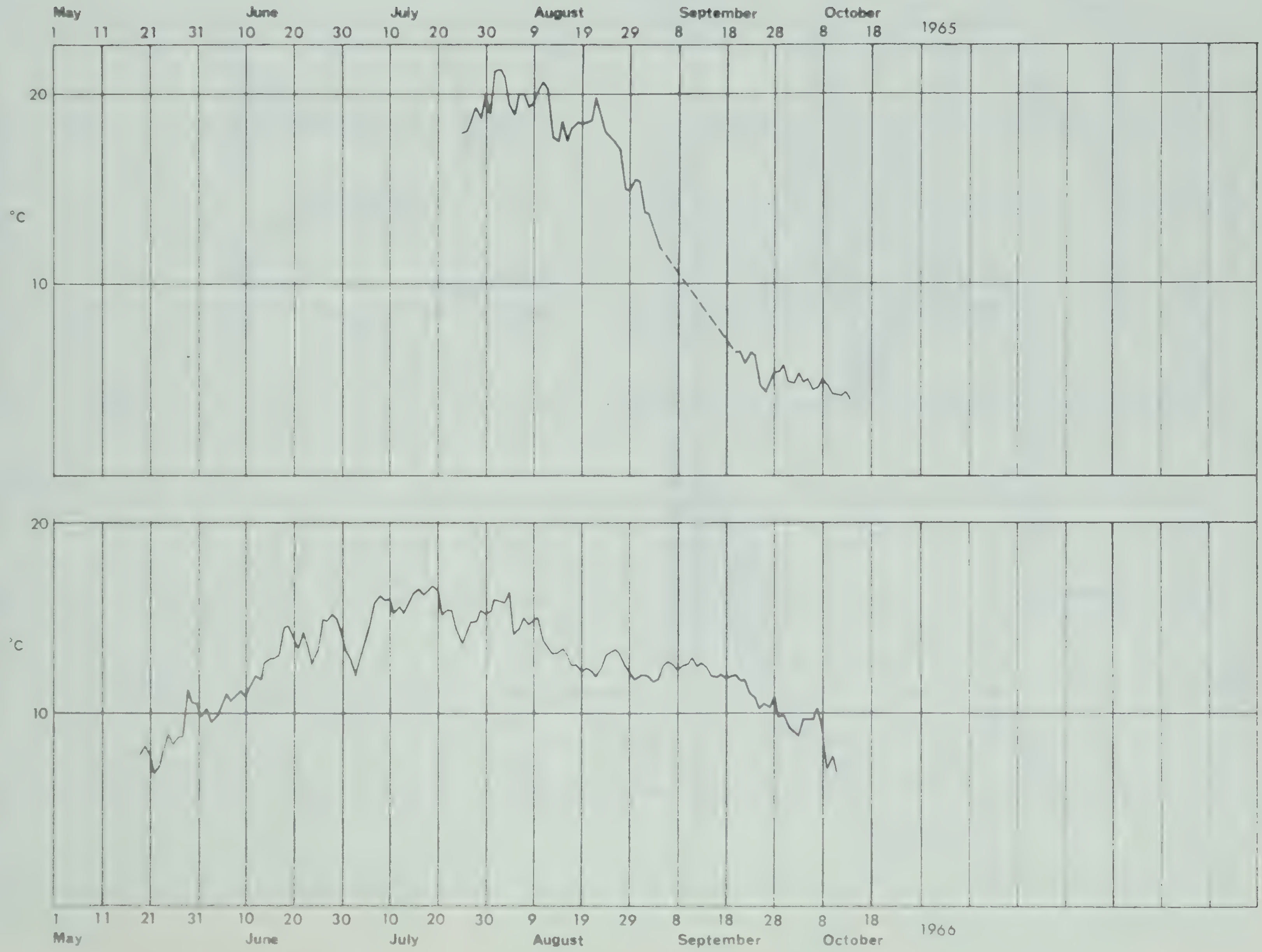
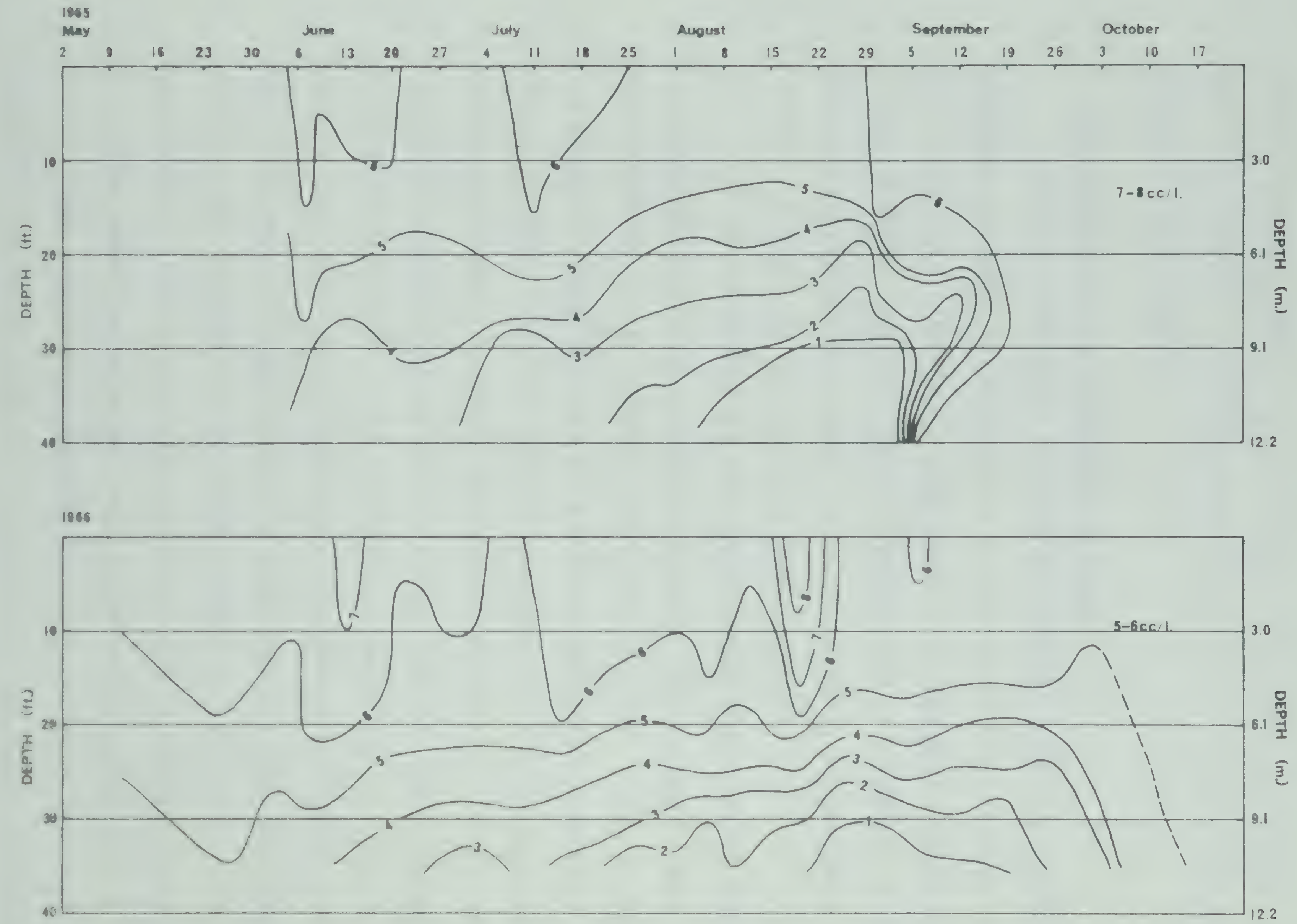

May
June
July
August
September
October
1
11
21
31
10
20
30
10
20
30
9
19
29
8
18
28
8
18
1965
20
°C
10
20
°C
10
1
11
21
31
10
20
30
10
20
30
9
19
29
8
18
28
8
18
1966
May
June
July
August
September
October

Figure 10. Seasonal distribution of dissolved oxygen (ml per liter) with depth in Swan Lake, 1965 and 1966.


1965
May
June
July
August
September
October
2 9 16 23 30 6 13 20 27 4 11 18 25 1 8 15 22 29 5 12 19 26 3 10 17
DEPTH (ft.)
10
20
30
40
DEPTH (m.)
3.0
6.1
9.1
12.2
7-8cc/l.
1966
5-6cc/l.

The high oxygen conditions in late August were induced by rainfall and were only temporary, persisting only until complete mixing of the surface waters had occurred.

8. The lake bottom and submerged vegetation

The lake bottom was surveyed by two SCUBA divers in October 1965. Submerged vegetation extended out to the 18 foot (5.5 m) contour. Water lily (*Nuphar* sp.) extended out from shore to an approximate depth of 10 feet (3.05 m). Several species of *Potamogeton* were present, as also were *Myriophyllum* and *Ranunculus*. Extensive areas in shallow water were covered by a dense mat of water moss (*Drepanocladus*).

It was noted that the lake bottom beyond the vegetated area became progressively softer from west to east. Echo sounder traces also indicate layers of soft sediment towards the east end. Since the natural flow of water through the lake and prevalent wind action combine to encourage a primary flow in an easterly direction it is to be expected that heavier sediments would be deposited at the west end of the lake and lighter sediments carried further towards the east end. This has led to a gradual filling in of the lake basin at the west end, around the mouth of the inlet. The boggy meadow to the west of the lake suggests that over a period of many hundreds of years such a process has taken place and that the lake was previously somewhat larger. There is evidence that the inlet is at present in the process of changing its mouth, its previous mouth having become very shallow and week-choked.

Three samples of bottom mud were collected on 23 June 1966 and analyzed by the Agricultural Soil & Feed Testing Laboratory in Edmonton (Table III). Nitrate nitrogen and phosphorus are both low. The low

TABLE III. Analysis of bottom muds from Swan Lake

Sample Number	Nitrogen (lbs./acre)	Phosphorus (lbs./acre)	Potassium (lbs./acre)	pH	Conductivity (m.mho)	Free Lime
1	nil	nil	282	7.5	0.8	low
2	nil	nil	152	8.0	0.6	high
3	1	nil	180	7.4	1.8	med.

Sample Locations:

1. West end of lake, mid-point: 15 feet (4.6 m).
2. Close to point on south shore: 10 feet (3.05 m).
3. Station III: 37 feet (11.3 m).

conductivity is indicative of low ionic content.

VI. PLANKTON

1. Zooplankton

The species of zooplankton identified from a series of plankton samples taken in 1965-66 are shown in Table IV. Only a small number of species was present and these were species commonly taken in samples from the limnetic zone of Alberta lakes.

Although *Chaoborus* larvae form a substantial part of the diet of the lake trout in Swan Lake, relatively few were taken in plankton samples. This is no doubt because *Chaoborus* larvae undergo marked diel-vertical migrations (Teraguchi and Northcote, 1966; Malueg and Hasler, 1967). The larvae generally inhabit the limnetic zone during the hours of darkness and move down into the deeper waters of the lake during the day. Since plankton samples were generally vertical hauls from a depth of 20 feet (7.0 m) taken during daylight hours it is not surprising that few *Chaoborus* larvae were taken.

Stahl (1966) has shown that coexistence of more than one species of *Chaoborus* in a lake is quite frequently observed. The only species identified from Swan Lake was *Chaoborus flavicans*, of which approximately twenty randomly selected specimens of the larvae were identified using the keys given by Cook (1956). These observations suggest that if a second species is present its numbers are relatively small compared with those of *C. flavicans*. *C. flavicans* has been identified as the only species present in a number of European lakes but it has generally been found coexisting with a second species (often *C. punctipennis*) in North America.

TABLE IV. Species of zooplankton in Swan Lake 1965-66

Cladocera

Daphnia magna Straus

Daphnia schødleri Sars

Copepoda

Diaptomus sp.

Diaptomus oregonensis Lilljeborg

Cyclops sp.

Cyclops varicans rubellus Lilljeborg

Diptera

Chaoborus flavicans Meigen

Rotifera

Keratella sp.

Asplanchna sp.

Filinia sp.

2. Phytoplankton

The species of phytoplankton present in a series of selected samples and their relative abundance is shown in Table V. Substantial numbers of *Ceratium hirundinella*, *Asterionella formosa* and *Dinobryon sertularia* are present for most of the summer. It is these three species, plus *Anabaena circinalis*, which contribute to the large plankton volumes found in June (Figure 11).

A "bloom" of *Aphanizomenon flos-aquae* commonly occurs in late September. The settled volumes at this period are much smaller than those recorded during June, since the organism is essentially restricted to within one meter of the surface. This is probably caused by the lower angle of incident light in the fall and the resultant reduction in light penetration. The large quantities of plankton carried from the lake into the outlet stream have, on occasions, seriously hampered visual observations of lake trout during the spawning season.

TABLE V. Relative abundance of phytoplankters in a selected series of plankton samples, Swan Lake 1965-66.

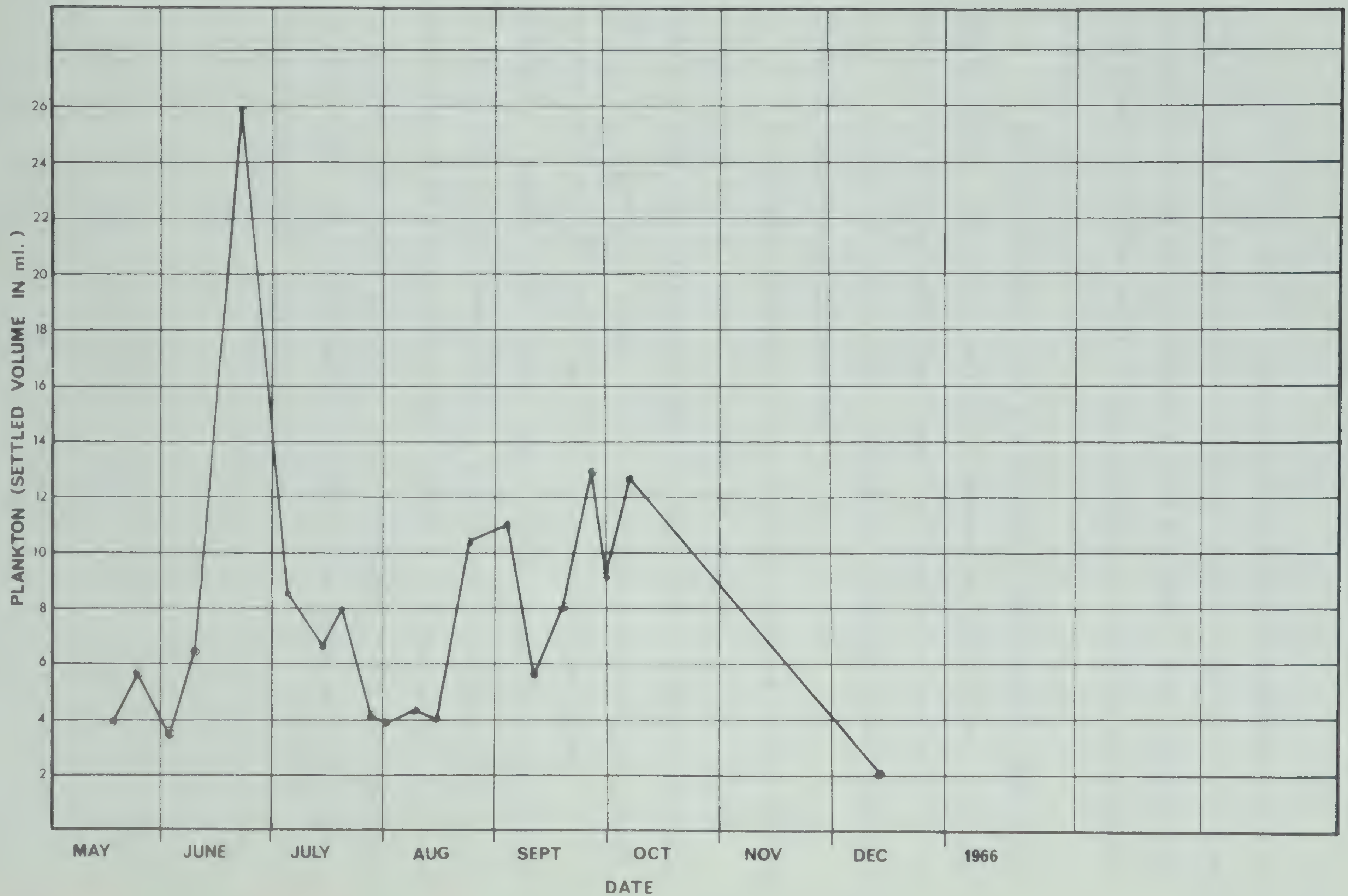
SPECIES	17 May 1965	24 June 1965	6 July 1965	18 July 1966	30 July 1966	6 Aug 1965	13 Aug 1965	23 Aug 1965	10 Sept 1966	17 Sept 1966	28 Sept 1965	13 Dec 1966
Chlorophyta												
Closterium sp. Nitzsch		*	*	*					*	*	*	
Planktosphaeria gelatinosa Smith									*	*	*	
Sphaerocystis schroeteri Chod.			*									
Staurastrum gracile Meyer										*		
Volvox tertius Meyer		*										
Pyrrophyta												
Ceratium hirundinella (O.F.M.) Schrank	**	**	**	*	**	**	*	**	**	**		
Chrysophyta												
Asterionella formosa Hass	***	***	**	*	**	**	***	**	**	**	***	*
Dinobryon sertularia Ehr.		**	**	**	***	***	**	**	*	**	*	
Fragilaria crotonensis var. prolongata Lyngb.	*	*	*						*	*	***	*
Melosira italica Ehr.			*	*			*	*	*	*	*	
Navicula sp. Bory				*								
Stephanodiscus astraea Ehr.	*										*	
Synedra ulna (Nitzsch) Ehr.										*		
Tabellaria fenestrata (Lyngb.) Kutz		*	*						*	*		
Cyanophyta												
Anabaena circinalis (Harvey) Robenhorst		**	*	*	**		**	**	**	*		
Anabaena macrospora var. robusta Gardner								*	*	*		
Aphanizomenon flos-aquae (1.) Ralfs.		*		*	**	**	**	**	**	***	***	*
Aphanocapsa rivularis Nagelli				**								
Coelosphaerium Kuetzingianum Naeg.			*	**	*	**	**	**	**	**	*	*
Microcystis aeruginosa Kuetz.		*	*					*				

*** Abundant

** Common

* Rare

Figure 11. Settled volumes of plankton at Station I, Swan Lake, 1966.


PLANKTON (SETTLED VOLUME IN ml.)
26
24
22
20
18
16
14
12
10
8
6
4
2
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
1966
DATE

VII. BOTTOM FAUNA

Tables VI and VII summarize the numbers of organisms and their displaced volumes from a series of bottom samples, most of them collected during the period May to October of 1965 and 1966. They illustrate the approximate distribution of the major groups of organisms with respect to depth.

The 0 to 20 foot (0 to 6.1 m) zone is dominated by Amphipoda and Hirudinea, the latter smaller in numbers but significant in volume. Insecta and Mollusca make significant contributions to the fauna in the 0 to 10 foot (0 to 3.05 m) zone. At depths exceeding 20 feet (6.1 m) the fauna is dominated by Chironomidae.

Dry weights measured from 20 randomly selected samples yielded a mean weight of 22.7 kg/ha. This may be compared with dry weights obtained from other selected lakes, the first eight of these containing lake trout populations (Table VIII). The first four lakes are clearly oligotrophic; the last four lakes are considered by the authors to be eutrophic. Deevey (1941) showed that the mean annual standing crop may be twice that of the summer standing crop while the maximum crop may be three times that of the summer crop. Although the mean weight used here is derived from summer data only, it is considered valid for comparative purposes since data collected on the other lakes referred to are also derived from surveys carried out in summer.

TABLE VI. Distribution of Swan Lake bottom fauna by depth zone, 1966 (number of organisms per square meter). Range in parentheses.

Depth Zone	Number of Dredgings	Mean number of organisms per square meter												
		Oligochaeta	Hirudinea	Amphipoda	Ephemeroptera	Odonata	Hemiptera	Trichoptera	Coleoptera	Culicidae	Chironomidae	Mollusca	Misc.	TOTALS
0-10 ft (0-3.05m)	38	13 (0-377)	35 (0-118)	911 (86-1765)	36 (0-323)	12 (0-140)	2 (0-11)	8 (0-54)	4 (0-71)	--	88 (0-968)	57 (0-398)	1 (0-11)	1167
11-20 ft (3.35-6.1m)	21	4 (0-22)	13 (0-54)	649 (129-1517)	10 (0-75)	8 (0-97)	--	4 (0-32)	--	1 (0-54)	107 (0-538)	4 (0-22)	--	796
21-30 ft (6.4-9.1m)	11	35 (0-194)	2 (0-22)	36 (0-215)	2 (0-22)	--	--	--	1 (0-11)	17 (0-108)	1142 (75-2109)	195 (0-366)	--	1430
31-38 ft (9.4-11.6m)	8	85 (0-183)	1 (0-11)	--	--	--	--	--	1 (0-11)	196 (0-1151)	1864 (829-3314)	9 (0-43)	--	2156
Mean Number		34	13	399	12	5	--	3	1	53	800	66	--	115
Per cent of Total		2.5	0.9	28.7	0.9	0.4	--	0.2	0.1	3.8	57.7	4.8	--	100.0

TABLE VII. Distribution of Swan Lake bottom fauna by depth zone, 1966 (ml per square meter). Ranges in parentheses.

Depth Zone	Number of Dredgings	Mean number of organisms per sq. meter in ml.												
		Oligochaeta	Hirudinea	Amphipoda	Ephemeroptera	Odonata	Hemiptera	Trichoptera	Coleoptera	Culicidae	Chironomidae	Mollusca	Misc.	TOTALS
0-10 ft (0-3.05m)	38	0.1 (0-1.1)	6.7 (0-28.0)	13.6 (1.1-30.1)	0.9 (0-7.5)	1.5 (0-21.5)	0.2 (0-1.1)	0.7 (0-4.3)	2.3 (0-80.1)	--	0.7 (0-6.5)	2.2 (0-16.1)	0.1 (0-1.1)	29.0
11-20 ft (3.35-6.1m)	21	0.2 (0-1.1)	3.0 (0-18.3)	8.8 (0-26.9)	0.5 (0-5.4)	0.4 (0-2.1)	--	0.5 (0-5.4)	--	0.1 (0-2.1)	1.4 (0-7.0)	0.3 (0-1.6)	--	15.2
21-30 ft (6.3-9.1m)	11	0.3 (0-1.1)	0.1 (0-1.1)	1.0 (0-7.0)	--	--	--	--	--	0.2 (0-1.1)	13.7 (1.1-22.6)	1.9 (0-4.3)	--	17.2
31-38 ft (9.4-11.6m)	8	0.9 (0-1.1)	--	--	--	--	--	--	--	1.0 (0-5.4)	15.7 (8.1-20.4)	0.1 (0-0.5)	--	17.7
Mean Number		2.5	2.1	5.8	0.5	0.4	0.3	0.4	0.1	0.1	7.9	0.6	1.1	19.7
Per cent of Total		2.0	12.7	29.5	2.0	2.5	0.5	1.5	3.1	0.5	40.1	5.6	--	100.0

TABLE VIII. Comparison of dry weights of bottom fauna from 12 selected lakes in North America

Lake	Surface area (km^2)	Mean depth (m)	Dry weight (kg/ha)	Source
*Cree Lake, Sask.	1155.0	14.9	1.6	Rawson (1959)
*Waterton Lake, Alta.	9.6	69.2	1.7	Rawson (1942)
*Minnewanka Lake, Alta.	13.0	38.1	4.5	Rawson (1942)
*Wollaston Lake, Sask.	2062.0	17.4	4.7	Rawson (1959)
*Lac La Ronge, Sask.	1295.0	11.0	8.9	Rawson (1959)
*Simcoe Lake, Ont.	725.0	17.0	12.0	Deevey (1941)
*Swan Lake, Alta.	2.0	6.2	22.7	Present Study
*Green Lake, Wisc.	29.7	33.1	27.0	Deevey (1941)
Paul Lake, B.C.	3.9	34.2	36.4	Rawson (1934)
Pinantan Lake, B.C.	1.5	12.0	45.0	Rawson (1934)
Mendota Lake, Wisc.	39.2	12.1	52.0	Deevey (1941)
Penask Lake, B.C.	7.8	11.0	56.0	Rawson (1934)

*Contain lake trout.

VIII. FISHES

Five species of fish are known to inhabit the lake. The two major species are lake trout *(Salvelinus namaycush)* and northern pike *(Esox lucius)*. There is a small population of white suckers (*Catostomus commersoni* Lacépede); only nineteen specimens were taken during the two-year study period. In addition to these, a small number of brown trout (*Salmo trutta* Linnaeus) are found. These fish have presumably entered the lake from the outlet creek, where there is a resident population which was introduced some years ago. Also present is the burbot (*Lota lota* Linnaeus), although to date only two very small specimens have been collected.

In an effort to determine whether any other species were present in the lake, a series of seine hauls was made at selected locations along the lake shore. Several areas of shallow water about one hundred feet long and fifty feet wide also were treated with two and one half per cent emulsified rotenone. Fifty-foot lengths of 3/4 inch mesh monofilament gill net were set at various locations and depths for 12-hour overnight periods. None of these methods yielded any additional species of fish.

The inlet creek is known to contain an introduced population of brown trout several miles above the lake. Within one mile of the lake only northern pike inhabit the stream.

The outlet creek was sampled in 1966 with a 230 volt D.C. electric shocking unit. The following species of fish were taken:

Brown trout (*Salmo trutta*)

Brook trout (*Salvelinus fontinalis* Mitchill)

Pike (*Esox lucius*)

White sucker (*Catostomus commersoni*)

Burbot (*Lota lota*)

Longnose dace (*Rhinichthys cataractae* Valenciennes)

Subsequently, one specimen of the spoonhead sculpin, (*Cottus ricei* Nelson), has been taken in the outlet.

The brook trout population has become established in Swan Creek only in the last three to four years, probably originating from stock formerly introduced into the Prairie Creek drainage.

IX. THE LAKE TROUT

A. INTRODUCTION

The lake trout (*Salvelinus namaycush*) is a char of essentially lacustrine habits. The name 'namaycush' is of Indian origin and means 'dweller of the deep' (MacKay, 1963).

The species is exclusively North American. Its present natural range has been outlined by Lindsey (1964) who states that: "Lake trout are confined at their southern limits to deep cool lakes, but towards the north they occur also in shallower lakes and even in rivers". Swan Lake lies close to the southern limits of the natural range of this species in western North America. In the Rocky Mountain area the only more southerly lakes containing natural populations of lake trout are Lakes Waterton and Minnewanka in Alberta (Cuerrier, 1954), St. Mary, Crossley, Glenns and Lower Two Medicine Lakes in Montana (Schultz, 1941) and Elk and Twin Lakes in Montana (Vincent, 1963). In most of these lakes introductions have been made so that the present stocks are no longer of purely native origin. The only other lake in the North Saskatchewan River drainage known to contain lake trout is Glacier Lake, Alberta (Cuerrier, 1954).

The species shows a natural preference for cool waters. Ferguson (1958), summarizing the field data of several workers, shows the species to have a preferred temperature range of 8.0 to 15.5C. Laboratory studies indicated a preferred temperature of about 12.0C. McCauley and Tait* showed that yearling lake trout preferred a temperature of 12.2C, regardless of efforts to acclimatize them at higher temperatures. Eschmeyer

*Quoted in Sport Fishing Institute Bulletin No. 149, April 1964.

(1956) gives the preferred temperatures of young lake trout as: Young of the year - 42-63F [5.6-17.2C] and age groups I and II - 39-53F [3.9-11.7C]. Eschmeyer (1957) and Daly *et al.* (1962) each state that "lake trout seldom remain for extended periods of time in waters exceeding 65F [18.3C]." Gibson and Fry (1954) showed that lake trout have an ultimate incipient lethal temperature of 23.5C, one of the lowest on record.

Very little information is available on the oxygen requirements of lake trout, although they are normally found in oxygen-rich waters. It can probably be assumed, however, that they will not enter waters containing less than 2.0 ml per litre for more than short periods, since concentrations below this level are rarely tolerated by other salmonids.

B. AGE AND GROWTH

Cable (1956) demonstrated the validity of the scale method for aging lake trout and also established criteria for distinguishing annuli on lake trout scales. She also stressed the need for experience with lake trout scales before a reader's interpretation of the scale pattern becomes reliable. In the present study most of the scale samples used were read at least three times by the author on different occasions before a conclusion was reached. No annuli of a doubtful nature were included, as a result, in cases of error, fish would tend to be aged below their correct age more frequently than above it.

Two series of samples were sent to N. V. Martin of Maple, Ontario, for checking. On the first series (28 samples) age readings showed a 93.1 per cent agreement. On the second series (59 samples) agreement between readings was 76.3 per cent. Since most of these samples were

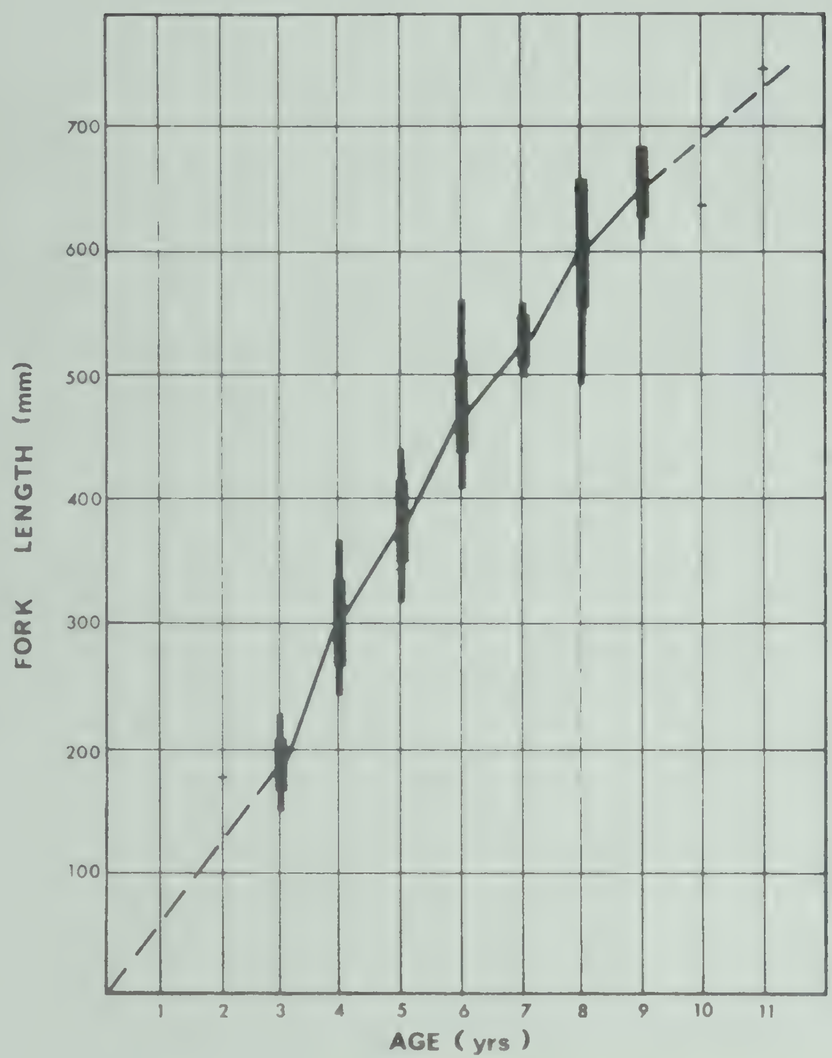
submitted as more difficult or "problem" scales the level of agreement may be considered satisfactory. The area of disagreement lay mostly in fish aged VIII and over and the difference between readings rarely exceeded one year. Accuracy of aging was also checked by means of scales from recovered tagged fish, previously sampled at the time of tagging.

Cable (1956) demonstrated the presence of an "O-mark" or false annulus in the first year of life in Lake Michigan fish. This appears to be characteristic of Lake Michigan fish only and has not been recorded by other authors, nor is it found in Swan Lake fish. Samples of all age classes have been collected in Swan Lake with the exception of young-of-the-year. Age class I fish have only been collected in pike stomach samples.

Most Swan Lake fish form their annuli during May and June. In preparing the growth curve (Figure 12), only fish collected during the period May 15 to June 15 were used. The lengths and weights used then represent mean values of these parameters for the fish, at the time of annulus formation (Table IX). The relationship between length and weight in Swan Lake trout is shown in Figure 13.

The growth rates of lake trout from various areas have been compared by Martin (1952) and Rawson (1961). Some correlation between growth rate and latitude has been demonstrated. In Figure 14 the growth rate of Swan Lake fish is compared with that of five other selected lakes. The growth rate is rapid in Upper Waterton Lake while that in Great Bear Lake is very slow. The lake trout of Lakes Opeongo, Redrock and Louisa, in Algonquin Park, Ontario, show moderate to fast growth rates.

Figure 12. Relationship of length and weight in Swan Lake lake trout with age. The heavy bars represent the standard deviation of the parameter and the lighter bars represent the range. All samples were taken during the period 15 May to 15 June in each year.


FORK LENGTH (mm)
700
600
500
400
300
200
100
1
2
3
4
5
6
7
8
9
10
11
AGE (yrs)

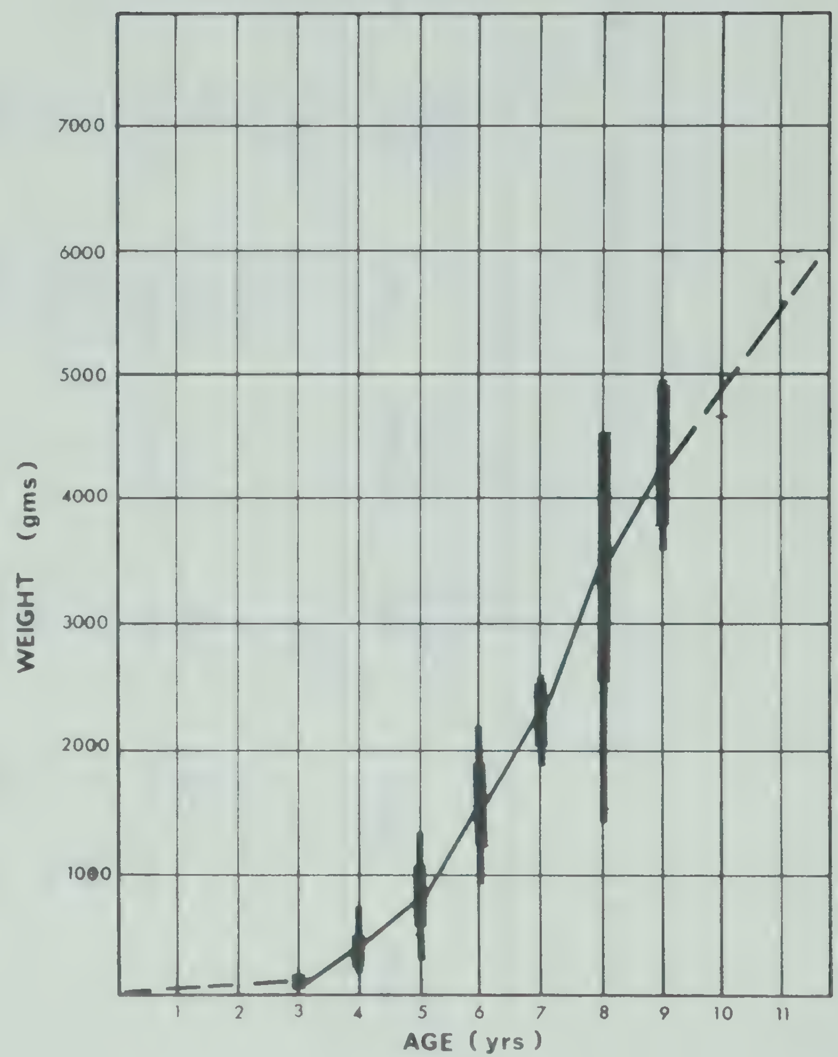

WEIGHT (gms)
7000
6000
5000
4000
3000
2000
1000
1
2
3
4
5
6
7
8
9
10
11
AGE (yrs)

TABLE IX. Mean weights and lengths of lake trout by age classes

Age Class	Mean Length (mm)	Range	Size of Sample	Mean Weight (gm)	Range	Size of Sample
II	178	--	1	80	--	1
III	190	147-221	16	95	60-100	16
IV	305	259-361	35	388	230-690	31
V	380	322-438	43	806	400-1,235	42
VI	479	410-560	27	1,611	950-2,200	26
VII	525	510-550	8	2,269	1,930-2,560	7
VIII	603	492-638	7	3,386	1,530-4,260	5
IX	651	612-678	4	4,350	3,630-4,930	4
X	632	--	1	4,575	--	1
XI	743	722-763	2	5,900	5,550-5,250	2

Figure 13. Relationship of length and weight in Swan Lake lake trout.

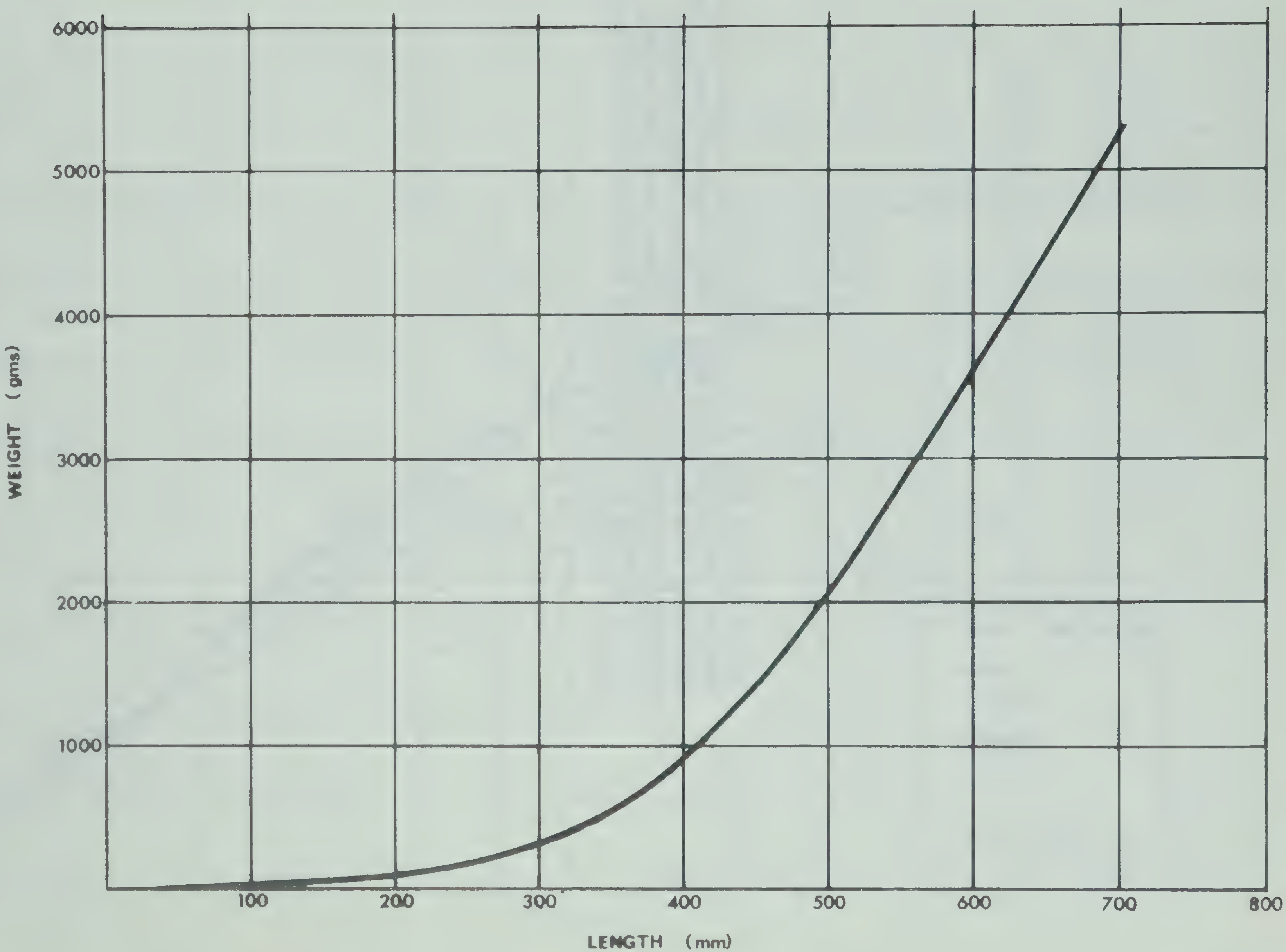
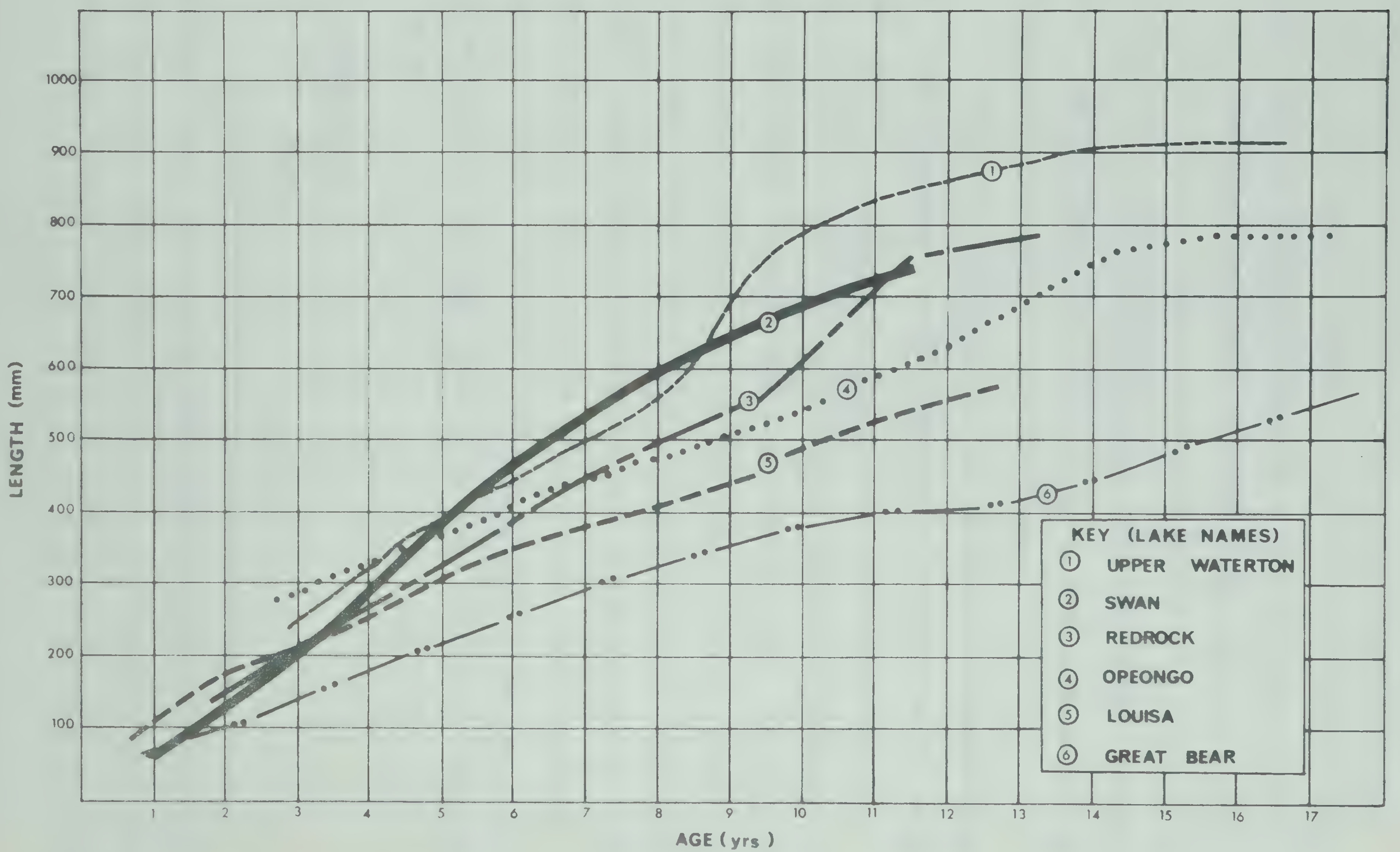

6000
5000
4000
3000
2000
1000
WEIGHT (gms)
100
200
300
400
500
600
700
800
LENGTH (mm)

Figure 14. Growth rate of lake trout from Swan Lake compared with that of lake trout from five other selected lakes. Data extracted from the following sources: Upper Waterton (Cuerrier and Schultz, 1957); Redrock and Louise (Martin, 1952); Opeongo (Fry, 1949); and Great Bear (Miller and Kennedy, 1948).


LENGTH (mm)
AGE (yrs)
KEY (LAKE NAMES)
1 UPPER WATERTON
2 SWAN
3 REDROCK
4 OPEONGO
5 LOUISA
6 GREAT BEAR

Both Redrock and Louisa Lake trout are planktonivorous in the early years of life. Distinct differences in growth rate are evident when Redrock Lake fish become piscivorous but Louisa Lake fish do not.

The growth rate of Swan Lake fish is slow during the first three years of life, a feature not unusual in lake trout, but from age IV onwards is rapid, comparing favourably with that in Upper Waterton Lake. Data from Seneca Lake, New York (Royce, 1943), suggest that the growth rate in that lake is of a similar order.

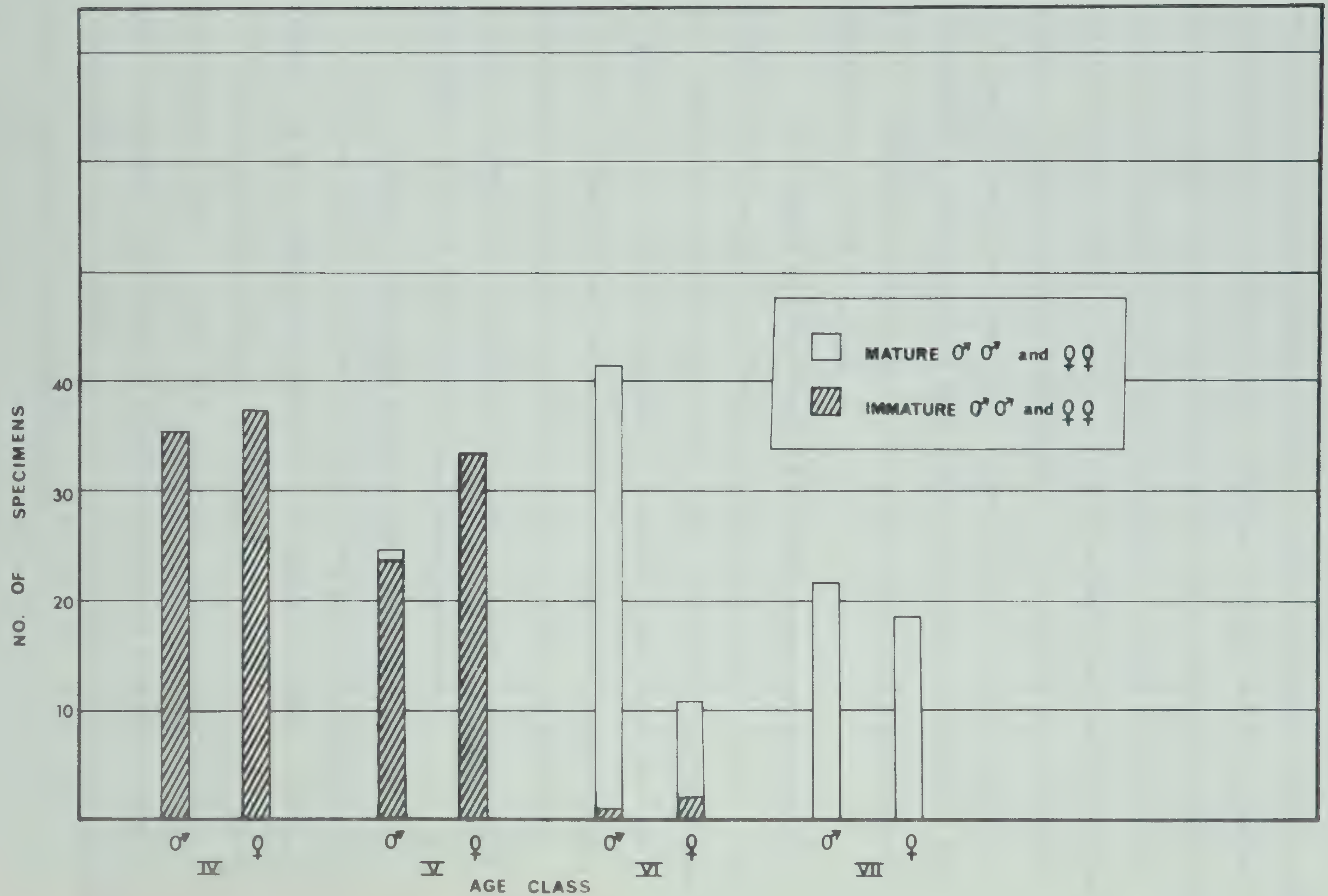
Figure 15 illustrates that most Swan Lake trout mature at age VI. A few males mature at age V and a few of either sex do not mature until age VII. A higher percentage of fish aged V are mature in Waterton Lake (Cuerrier and Schultz, 1957), Lake Simcoe (McCrimmon, 1956), Keuka Lake (Royce, 1943) and Louisa Lake (Martin, 1952). In Great Bear Lake (Miller and Kennedy, 1948) the trout begin to mature at age XIII. In many lakes (Kennedy, 1954; Rawson, 1961) the number of mature fish increases progressively through several age classes and maturity is more closely related to size. That the range of sizes within a given age class in Swan Lake is relatively small may account for the fact that most fish mature at the same age. Most of the trout mature at a length close to 500 mm.

C. FEEDING HABITS

1. General

Various methods have been devised for studying the feeding habits of fishes. These methods were summarized by Gerking (1962). In this study the 'volume' method has been used, in combination with 'frequency of occurrence.' Most methods do not take into account the relative

Figure 15. Maturity of Swan Lake lake trout by sex and age class.



MATURE ♂♂ and ♀♀
IMMATURE ♂♂ and ♀♀
40
30
20
10
NO. OF SPECIMENS
♂ ♀
IV
♂ ♀
V
♂ ♀
VI
♂ ♀
VII
AGE CLASS

rates of digestion of different organisms or the relative percentage of each organism absorbed (Gerking, 1962). Hess and Rainwater (1939) studied the relative rates of digestion of a series of organisms and suggested the determination of "evaluation factors" for each species and food item. In the current study most of the organisms were in good condition and little digestion had taken place. Food organisms were removed from the stomachs in the field and placed in vials. Since no stomachs complete with contents were returned to the laboratory it was not possible to determine the relationship of food volume to fullness of stomach. The results obtained are used only as an indication of food preferences and availability of food organisms.

The content of the stomachs have been summarized to show the variation with length class (Table X), and with season (Table XI). The fish contained in these stomachs were almost exclusively bait fish used by anglers and so may be considered as unnatural food items for this population. The diet may be separated into planktonic (*Chaoborus* sp.) and bottom dwelling spcies. Of the latter, the Amphipoda and Chironomidae are perhaps the most important. Mayfly nymphs and Hemiptera of ths family Corixidae are preferred items when available.

2. <u>Size of lake trout with relation to feeding habits</u>

From Table X it is evident that there are no significant differences in diet between the various length classes studied. Hartman (1958) demonstrated a relationship between mouth size and food size in young rainbow trout. It may be assumed that the young lake trout in Swan Lake have a less varied or a different diet as a result of their smaller mouth size. However, the lack of young lake trout in the samples made it impossible to substantiate this.

TABLE X. Stomach contents of Swan Lake lake trout showing variation by length classes 1965-1966

	LENGTH CLASS (mm)												TOTAL	
	100-199		200-299		300-399		400-499		500-599		600-699			
	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Volume
No. of stomachs	6		62		135		66		33		18		320	
% empty stomachs	16.7		1.6		16.3		12.1		9.1		0		10.9	
FOOD ITEM														
Fish	-	-	1.6	100	2.6	83.9	8.6	61.2	10.0	38.3	27.8	49.6	6.0	60.0
Crustacea														
Amphipoda	-	-	41.0	38.5	37.2	20.5	56.9	29.4	66.7	33.0	72.2	29.0	46.7	26.5
Cladocera	-	-	8.2	48.1	2.6	30.0	5.2	74.1	6.7	73.4	16.7	14.0	5.6	46.3
Insecta														
Hemiptera	-	-	4.9	12.1	24.8	7.5	43.1	5.6	40.0	0.8	44.4	1.0	26.7	5.3
Coleoptera	-	-	-	-	4.4	2.5	17.2	3.7	13.3	0.2	16.7	1.3	7.7	2.4
Odonata	-	-	6.5	5.1	-	-	3.4	1.7	10.0	1.4	11.1	0.1	3.8	2.5
Trichoptera	-	-	-	-	8.0	4.8	10.3	2.9	6.7	0.6	5.6	1.1	6.3	3.4
Ephemeroptera	-	-	24.6	36.9	36.3	18.8	39.6	6.1	30.0	0.6	33.3	1.1	33.0	15.7
Diptera (misc)	-	-	-	-	0.9	1.5	-	-	3.3	0.2	-	-	0.7	0.8
Chaoborinae	100	100	88.5	59.8	84.1	74.8	86.2	77.0	83.3	69.2	77.8	57.5	85.3	70.8
Chironomidae	20.0	n.m.	44.3	19.0	52.2	20.3	60.3	12.1	53.3	6.0	61.1	4.9	52.3	15.3
Hirudinea	-	-	6.6	34.8	2.7	4.9	5.2	17.8	6.7	2.3	22.2	8.1	5.6	15.2
Mollusca	-	-	-	-	2.7	1.0	1.7	0.5	-	-	11.1	0.3	2.1	0.6
Nematomorpha	-	-	3.3	26.2	1.8	0.6	6.9	0.8	-	-	-	-	2.8	7.1
Plant Material	-	-	-	-	-	-	5.2	5.6	6.7	1.5	22.2	0.7	3.2	2.5
Unidentified	-	-	3.3	50.0	0.9	6.7	1.7	2.0	6.7	3.0	11.1	15.9	3.2	18.3

n.m. - not measurable

TABLE XI. Stomach contents of Swan Lake lake trout showing seasonal variation 1965-1966

	MONTH													
	MAY		JUNE		JULY		AUGUST		SEPT		OCTOBER - APRIL		TOTAL	
	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Volume
No. of stomachs	55		96		39		58		53		33		334	
% empty stomachs	0		3.1		7.7		24.1		28.3		0		10.5	
<u>FOOD ITEM</u>														
<u>Fish</u>	12.7	53.0	5.4	48.5	-	-	2.3	91.2	5.3	72.6	21.2	81.2	7.4	64.4
<u>Crustacea</u>														
Amphipoda	49.1	23.7	36.6	21.2	44.4	17.3	47.7	38.7	63.2	31.8	63.6	60.0	47.8	31.2
Cladocera	20.0	44.2	-	-	-	-	11.4	45.1	2.6	30.0	-	-	5.7	43.6
<u>Insecta</u>														
Hemiptera	25.5	2.9	18.3	1.5	16.7	0.2	27.3	4.6	57.9	9.8	30.3	6.4	27.1	5.0
Coleoptera	9.1	7.0	11.8	0.8	11.1	1.4	-	-	-	-	-	-	6.7	2.5
Odonata	7.3	1.8	6.5	2.5	2.8	2.8	2.3	n.m.	-	-	9.1	1.9	5.0	2.0
Trichoptera	9.1	3.4	2.2	4.5	2.8	0.3	4.5	0.3	7.9	6.4	9.1	1.7	5.4	3.2
Ephemeroptera	30.9	2.2	34.4	11.1	16.7	15.1	4.5	1.1	42.1	6.7	84.8	35.6	33.8	15.7
Diptera (misc)	1.8	0.4	1.8	n.m.	-	-	-	-	-	-	-	-	0.7	0.2
Chaoborinae	90.9	72.1	96.8	77.4	100.0	86.3	79.5	59.7	71.1	44.9	18.2	33.0	81.6	70.4
Chironomidae	30.9	6.7	55.9	10.2	44.4	7.1	77.3	21.3	72.7	27.9	6.1	1.7	49.8	15.2
<u>Hirudinea</u>	9.1	23.8	7.5	6.7	-	-	2.3	28.6	2.6	16.2	3.0	37.0	5.0	16.5
<u>Mollusca</u>	3.6	0.3	-	-	-	-	2.3	n.m.	5.3	1.1	6.1	7.4	2.3	2.5
<u>Nematomorpha</u>	3.6	0.4	6.5	9.2	-	-	-	-	-	-	-	-	2.7	7.0
<u>Plant Material</u>	7.3	4.8	3.2	0.9	2.8	0.4	2.3	0.2	2.6	0.5	6.1	n.m.	4.0	1.9
<u>Unidentified</u>	7.3	8.9	6.5	2.4	-	-	2.3	13.8	2.6	50.0	3.0	18.2	4.3	10.1

n.m. - not measurable

3. Seasonal changes in diet

During the period October to April, lake temperatures are relatively uniform and oxygen conditions generally remain favourable, with the result that few physical limitations are placed on the free movement of the lake trout. All food items are available to the fish and the diet at this time presumably represents the preferred one for this population. Martin (1954) showed, however, that there may be marked changes in diet during the winter. Changes in the diet at other seasons are the result of non-availability of certain items, generally because of temperature or oxygen limitations, or because of the hatching of larval and nymphal stages (Table XI).

A slight reduction in the availability of amphipods is evident during the period June to August as thermal stratification prevents the trout from entering much of the littoral area. The reduction is more marked in the Hemiptera, a group generally restricted to the 0 - 10 foot (0-3.5 m) depth zone (Table XI). Fewer mayfly nymphs are also taken, but this may result from the emergence of large nymphs and the small size of early instars of other species of the group at this season. Molluscs, although not restricted to the littoral zone, are absent from the diet during the summer months.

Lake trout have been taken in gill nets in Swan Lake at depths where dissolved oxygen levels were between 1.0 and 2.0 ml per liter. The fish were not recovered alive and it seems probable that they were only making short forays into these depths to feed.

4. Unusual character of diet

It is probable that the lake trout and pike populations of Swan Lake are ecologically separated during the period of thermal stratification.

At other seasons young pike are presumably a potential source of food available to the lake trout. None, however, were recorded in lake trout stomachs during the study. The natural diet of this population of lake trout does not normally seem to contain fish, apparently a unique situation.

Fish is the primary food item of most populations of lake trout, except in younger age classes (Rawson, 1961; Dryer *et al.*, 1965). Other authors have reported varying proportions of insects and crustaceans in the diet (Miller and Kennedy, 1948; Cuerrier, 1954; Cuerrier and Schultz, 1957; Hildebrand and Towers, 1927). Martin (1966) summarized data from a number of lakes in Algonquin Park, Ontario, where the lake trout may be piscivorous or planktonivorous to varying degrees, dependent upon available food supply in the summer months. In a more detailed study of Louisa and Redrock Lakes, Martin (1952) showed that during thermal stratification the lake trout did not enter the warm waters of the epilimnion in Louisa Lake to feed on the fish there and so were restricted to a diet of plankton. Main items in the diet were Crustacea, *Chaoborus* sp. larvae, and larvae and pupae of Chironomidae. Martin (1952) also stated that specimens of a single group or species often made up the whole or most of the contents of an individual stomach. This was also true in Swan Lake, although it is not well demonstrated in the accompanying tables. Individual specimens often contained almost exclusively food items of one species or closely allied taxonomic group. This indicates that the plankton feeding habit is not a random straining of a mass but a selection of individuals or groups of individuals.

5. Per cent of empty stomachs

Table XI shows a gradual increase in the number of empty stomachs throughout the summer, reaching a peak in the fall. This feature was also noted by Martin (1952) in Louisa Lake. The reason for this period of reduced feeding activity is unknown. The approach of spawning may be a factor although no marked difference was evident in the proportion of feeding and nonfeeding fish among the mature and immature trout.

D. TAXONOMIC COMPARISONS

1. Introduction

It is reasonable to suppose that an isolated population of trout such as that in Swan Lake might tend to develop morphological differences which would distinguish it from other populations of lake trout. This has not been commonly noted among lake trout (Rounsefell, 1963). Since the diet of this population is atypical for the species, characters affected most by this aspect of its natural history might be expected to show measurable differences. Selected characters from a sample of Swan Lake fish were compared with those from a sample from Cold Lake, in eastern Alberta, where the lake trout are piscivorous, feeding almost exclusively on ciscoes, *Coregonus artedii* LeSueur.

2. Pyloric caeca

The numbers of pyloric caeca from a sample of 66 fish from Swan Lake were compared with the numbers from a sample of 42 fish from Cold Lake. The numbers of caeca ranged from 81 to 139 in Swan Lake and from 95 to 157 in Cold Lake, to give means of 114.4 and 127.8 respectively. These were compared by Student's t-test, which indicated a significant

difference at the 99 per cent level.

All the fish sampled from Swan Lake exceeded 250 mm in length and all the fish from Cold Lake exceeded 400 mm. Martin and Sandercock (1967) demonstrated a relationship between number of caeca and length of fish in lake trout from three lakes in Algonquin Park, Ontario. In these lakes the increase in numbers of caeca levelled off when the fish reached a length of approximately 300 mm. No relationship between length of fish and numbers of caeca was evident in the samples from Swan Lake and Cold Lake and it is assumed that in each of these two groups the fish had all developed their full complement of caeca.

Martin and Sandercock (1967) failed to show any relationship between feeding habits and numbers of pyloric caeca, although they obtained significant differences at the 99 per cent level between counts on different lakes. The difference obtained in the current study may or may not be directly related to the differences in feeding habits. Further comparisons with other piscivorous populations would be necessary to substantiate this. It is of note, however, that the diet of lake trout in Cold Lake is more typical of the species than that of the Swan Lake trout. The mean pyloric caecum count obtained from Cold Lake fish agrees fairly closely with means for the species given by Vladykov (1954) of 137.9, and by Morton and Miller (1954) of 126.7, while the mean for Swan Lake fish is much smaller.

3. Gill rakers

Gill raker counts were made on 159 lake trout from Swan Lake and 44 lake trout from Cold Lake. All counts were made on the first arch on the left side of the fish and all rudimentary rakers were included.

Separate counts were also made on the upper and lower limbs of each arch.

Martin and Sandercock (1967) noted the presence of a row of accessory gill rakers on the medial surface of the gill arch of Algonquin Park lake trout. No rakers of this description were noted in Swan Lake fish.

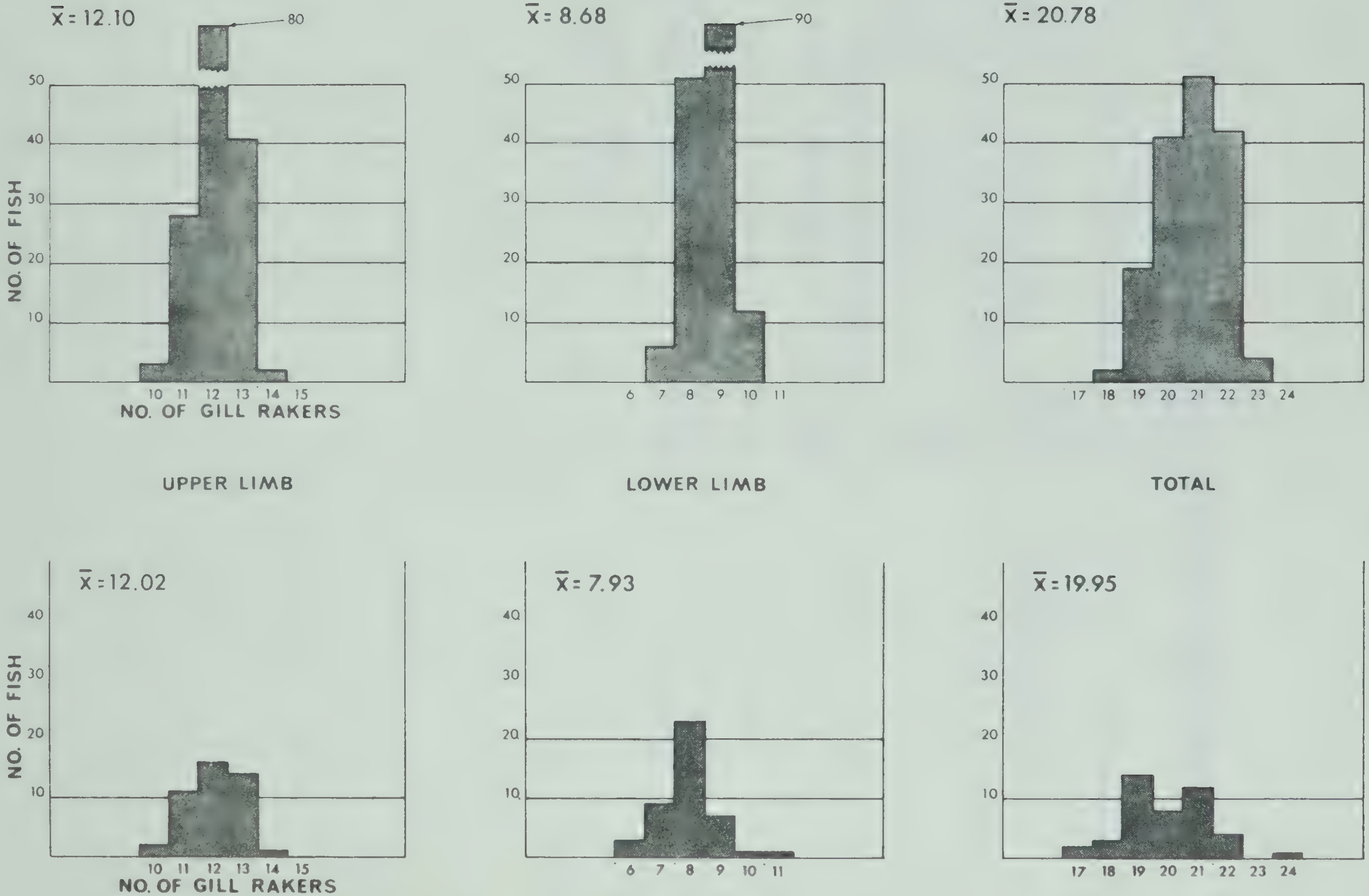
No consistent trends were apparent in the numbers of gill rakers as related to the size or the sex of the trout. The distribution of the gill raker counts in the series of fish is shown in Figure 16.

Table XII summarizes the results of Student's *t*-tests carried out on the two series of counts. A significant difference at the 99 per cent level was found between the means of the total counts. No significant difference was found between the means of counts on the upper limbs but a significant difference at the 99 per cent level was found between the means of counts on the lower limbs. Differences between the total counts are, therefore, primarily the result of differences in the counts on the lower limbs.

It is of note that the mean gill raker counts for both of these populations are lower than the means reported by Qadri (1964) and Martin and Sandercock (1967). A comparison of these values is given in Table XIII. If the counts are compared with means taken from eastern populations the Swan Lake count is closer to the means of these eastern populations, whereas the Cold Lake count is unusually low. Before any valid conclusions can be drawn, therefore, it is suggested that counts should be made on other western populations to determine whether there are regional differences throughout the range of the species which might mask any differences between populations possibly related to diet.

Figure 16. Numbers of rakers on first gill arch of lake trout from Swan Lake and Cold Lake. Counts for the upper and lower limbs of the arch are plotted separately and in combination.

Swan Lake



Cold Lake

TABLE XII. Summary of t-test results on counts of gill rakers from Swan Lake and Cold Lake trout, 1966

Location	Characteristic	No. in sample	Mean ± standard deviation	t
Swan Lake	upper limb	159	12.10 ± 0.77	0.53
Cold Lake	upper limb	44	12.02 ± 0.93	
Swan Lake	lower limb	159	8.68 ± 0.70	4.79**
Cold Lake	lower limb	44	7.93 ± 0.97	
Swan Lake	total	159	20.78 ± 1.09	3.61**
Cold Lake	total	44	19.95 ± 1.43	

** Significant at the 99 per cent level

TABLE XIII. Mean gill raker counts and ranges from several selected populations of lake trout

Source	N	Range	$\overline{X}$
Swan Lake	159	18-23	20.78
Cold Lake	44	17.24	19.95
L. Louisa (Martin and Sandercock 1967)	274	18-26	22.26
Happy Isle Lake (Martin and Sandercock 1967)	188	17-25	22.05
L. Opeongo (Martin and Sandercock 1967)	468	16-25	21.06
L. Louisa (Qadri 1964)	-	21-24	22.80
L. Lavielle (Qadri, 1964)	-	20-24	22.20

4. Length of longest gill raker

The length of the longest gill raker on the first gill arch was measured on 43 lake trout from Cold Lake and 171 lake trout from Swan Lake. The same gill raker was measured in each case. The relationship of this measurement to the fork length of the fish is shown for each population in Figure 17. This relationship is well-defined in Swan Lake fish but shows greater variability in Cold Lake fish.

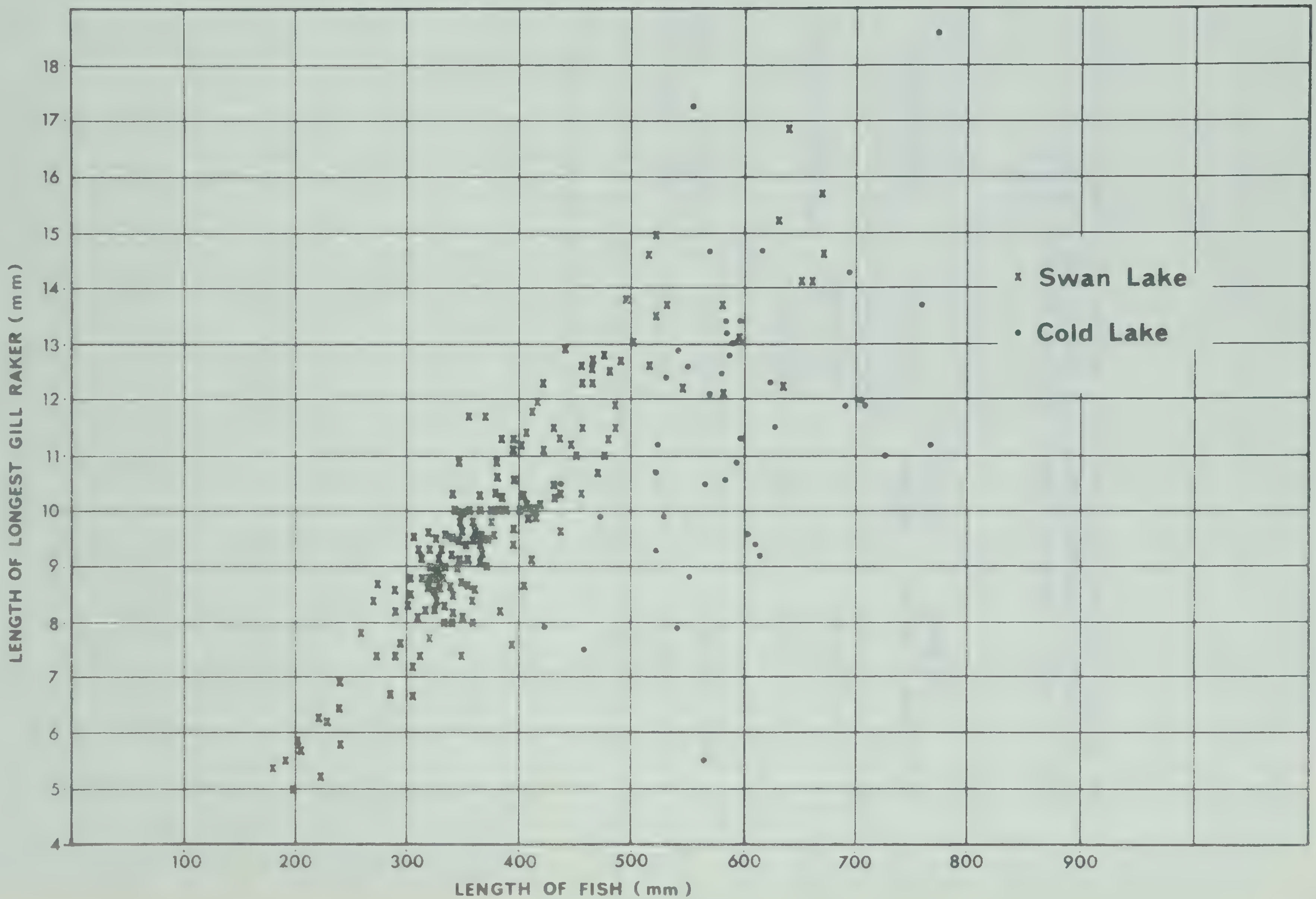
To compare gill raker length in the two populations while minimising the effect of length of fish, samples were compared which fell within the length range 500 - 700 mm. The results of Student's *t*-tests carried out on these samples (Table XIV) show that while the difference between the mean lengths was not significant the difference between the mean gill raker lengths was significant at the 99 per cent level. The existence of such a difference between the gill raker lengths of the two populations is perhaps indicative of some adaptation in Swan Lake fish to facilitate the straining of plankton organisms, a function only infrequently required in fish which are primarily piscivorous. It would, of course, be necessary to test this against other piscivorous populations before its validity could be accepted.

Comparison of these gill raker lengths with those taken by Martin and Sandercock (1967) indicates a greater mean length in Swan Lake fish, but it is very doubtful if the results are comparable. Differences in technique could easily explain these apparent differences.

5. Lateral line scales

Scale counts from 36 Swan Lake trout and 43 Cold Lake trout were compared. The number of lateral line pores was counted. This method

Figure 17. Relationship of gill raker length to body length in samples of lake trout from Swan Lake and Cold Lake, illustrating the relative variability of the two populations.



x Swan Lake
• Cold Lake
LENGTH OF LONGEST GILL RAKER (mm)
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
100
200
300
400
500
600
700
800
900
LENGTH OF FISH (mm)

TABLE XIV. Summary of results of t-tests for lengths of fish and lengths of longest gill raker between two samples of fish (500-700 mm fork length) from Swan Lake and Cold Lake

Characteristic	Location	No. in sample	Mean ± standard deviation	t
Length of fish (mm)	Swan Lake	17	586.0 ± 62.3	2.02
	Cold Lake	31	581.4 ± 42.7	
Length of longest gill raker (mm)	Swan Lake	17	13.89 ± 1.39	4.30**
	Cold Lake	31	11.60 ± 2.32	

** Significant at the 99 per cent level.

gives a count lower than that of the number of oblique rows of scales (Morton and Miller, 1954). Means for the two series were 120.3 for the Swan Lake fish and 120.9 for the Cold Lake fish. There was no significant difference between them.

E. REPRODUCTION

1. Sexual dimorphism

Sexual differences, generally in body coloration and head conformation, are common among salmonids. The lake trout is an exception and such differences have rarely been reported. Royce (1943) described color changes in males when they were sexually excited on the spawning ground, but these changes were only short-lived and did not persist when the fish were removed from water. DeRoche and Bond (1957) noted the presence of a wide black band and a somewhat more pointed snout on male trout during spawning season. They described the females as having bright strawberry coloration and swelling about the vent.

No obvious sexual differences were noted in Swan Lake trout. No differences in head conformation could be detected nor any difference in coloration. When removed from the water males could generally be separated from females by a rougher feel to the body surface. This roughness is probably associated with the pearl organs described by Vladykov (1954). This character was found reliable with all except the youngest mature fish, but was only evident during the period of the spawning run.

2. Fecundity

Very few data were obtained on the fecundity of Swan Lake trout. Sample egg counts were made on seven fish and estimates of the totals determined by extrapolation, using volume displacement measurements from

both the sample and the whole ovary. Lengths of fish used ranged from 578 to 672 mm and weights from 3240 to 4575 gms. Egg counts ranged from 4312 to 9370 (1298-2296 per kg), giving a mean of 1872 eggs per kg (858 per lb).

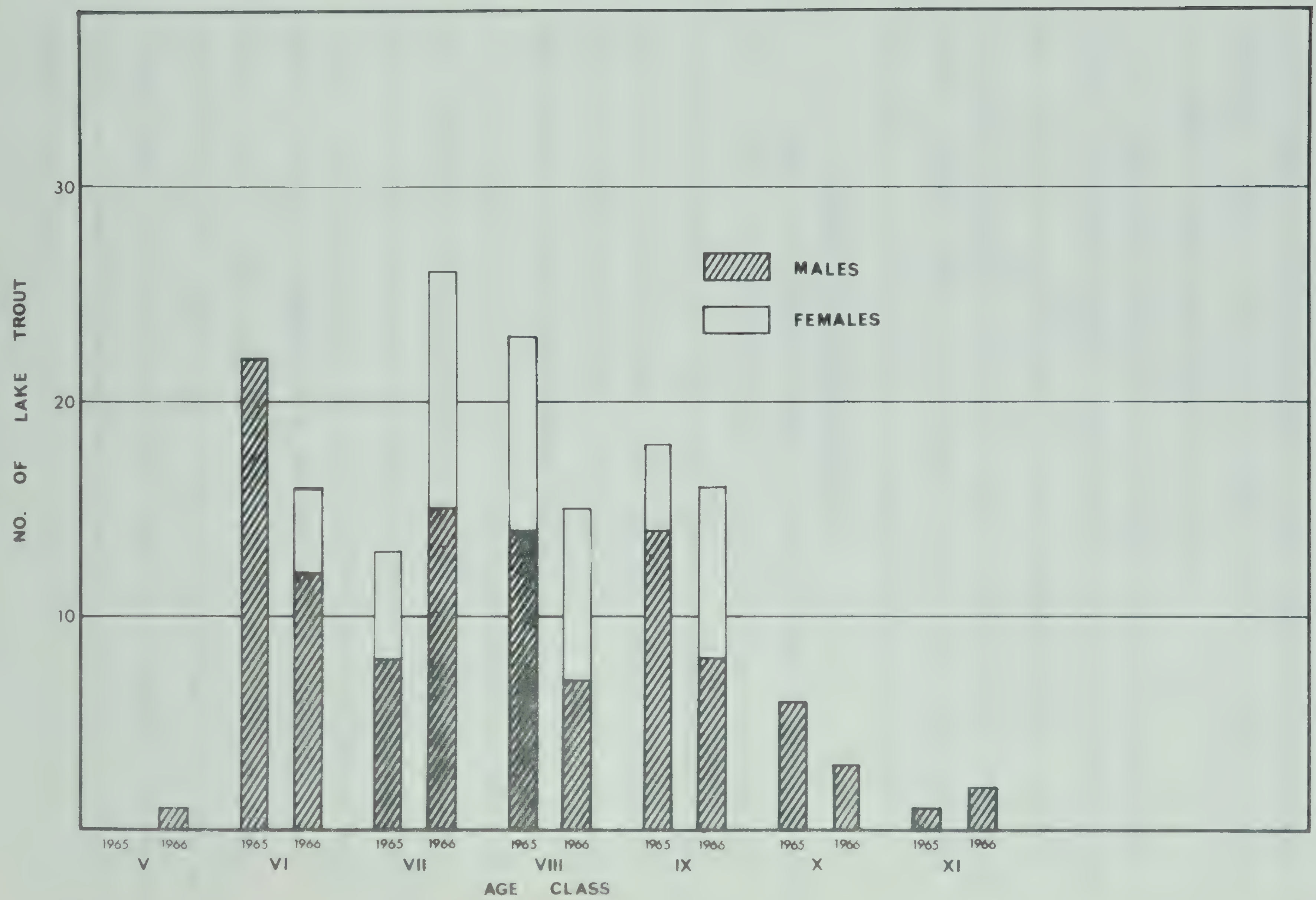
There was a wide variation in egg counts in similar sized fish in Swan Lake. Similar results have been reported by several authors and summarized by Eschmeyer (1955); average counts varied from 646 per lb (1424 per kg) in Lake Superior to 721 per lb (1590 per kg) in Lake Ontario. Eschmeyer showed that in Lake Superior there was a gradual increase in average egg production per pound of fish with increasing size although very broad ranges were encountered in fish within the same one inch (25.4 mm) or one lb (0.45 kg) interval.

3. Age of maturity

Figure 18 shows the ages and sex of the fishes in the spawning run in 1965 and 1966. In the samples obtained the number of males in any age class either equalled or exceeded the number of females. This may be a result of the method of sampling; the fish were collected close to but not on the spawning bed and males have been observed elsewhere to move more freely in and around the spawning area than females (Seguin and Roussel, unpublished). Martin (1957) obtained 85 per cent males in tagging operations on Lake Louisa and 60 to 80 per cent in Lake Opeongo. Similar results were reported by Eschmeyer (1955). Loftus (1958), describing a run in the Montreal River, reported that males were predominant in the early and late parts of the run but that the sex ratio was approximately one to one at the peak.

Figure 18 also indicates an absence of females of age X or older

Figure 18. Relative numbers of mature males and females of each age class in the spawning run, Swan Lake, 1965 and 1966.


MALES
FEMALES
NO. OF LAKE TROUT
30
20
10
1965
1966
V
VI
VII
VIII
IX
X
XI
AGE CLASS

in the spawning population. This could result from a higher mortality rate in females of these age groups or from a failure to develop eggs in older fish. There is, however, no evidence from other observations in this study to suggest that the latter is true.

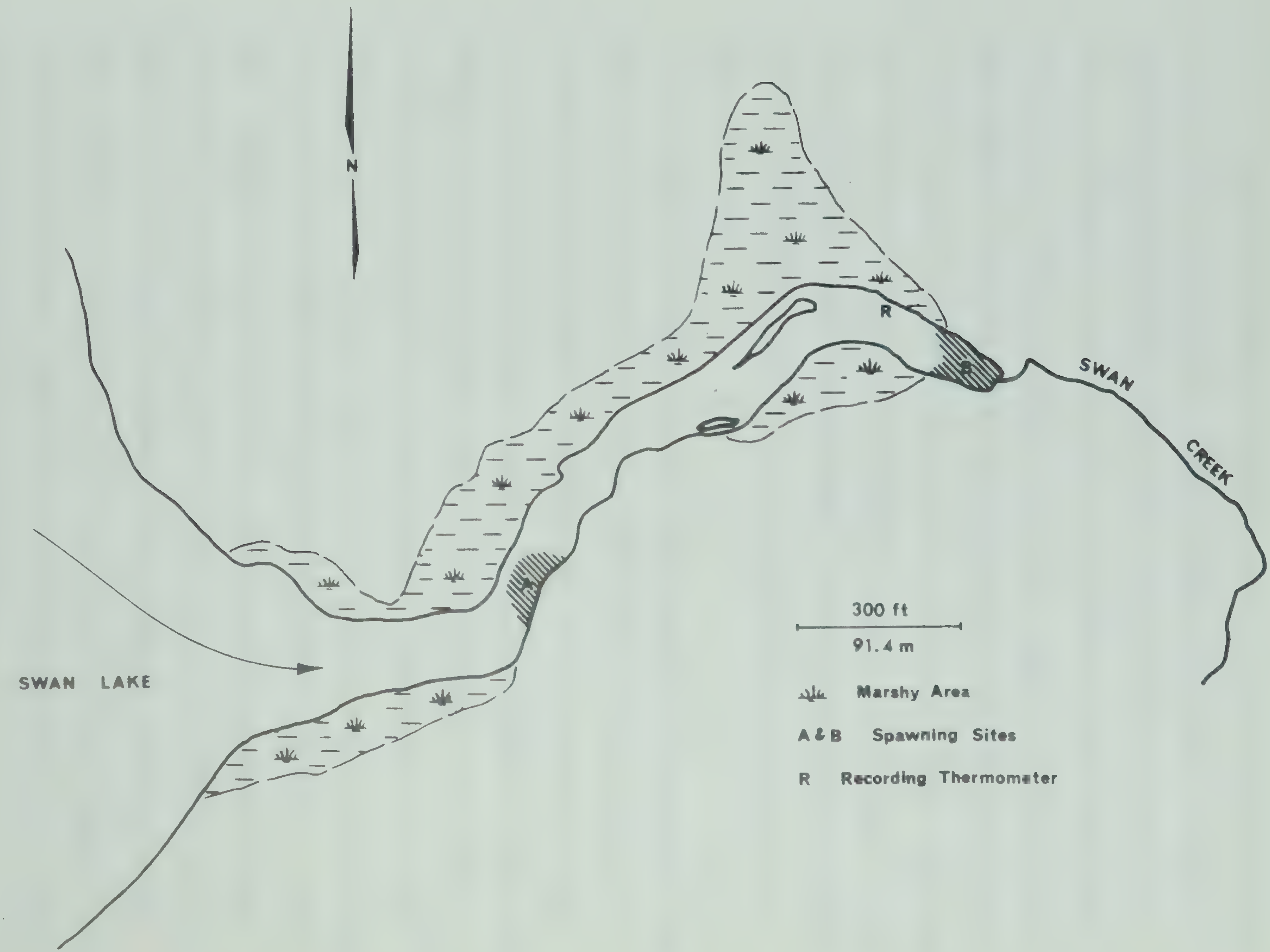
Lake trout in more northerly areas such as Great Slave Lake (Kennedy, 1954) and Great Bear Lake (Miller and Kennedy, 1948) may only spawn every second or third year. In more southerly areas, even in oligotrophic conditions, the trout appear to spawn annually (Hanson and Wickwire, 1967). There is no evidence to suggest that lake trout in Swan Lake do not spawn annually once they have reached maturity.

4. Description of spawning areas

Lake trout commonly spawn in lakes, on areas of gravel or rubble which are kept free of mud and sand by wave action or water currents (Royce, 1943; DeRoche and Bond, 1957). Depths of spawning sites vary but are generally less than 18 meters (59.0 ft) and commonly less than 6 meters (19.7 ft) (Martin, 1957). Selection of site appears to depend upon currents or other water movement (Royce, 1951).

In Swan Lake the lake trout spawn in the outlet stream of the lake. Figure 19 shows the location of the spawning site in relation to the lake. Area B represents the area where most of the spawning activity occurs. The stream bottom at this point varies from soft mud to rubble three to eight cm in diameter. At the lower end of this section is a shallow ridge, all that remains of an old beaver dam. This ridge has maintained the water level in this section of the stream and in the lake for many years, but high flows in 1965 reduced the height of the ridge so that water levels in the section dropped significantly at certain periods during 1966.

Figure 19. Map illustrating the location of lake trout spawning areas (Areas A and B) in lower Swan Creek, Alberta. "R" indicates the location of the recording thermometer in the creek. The direction of flow is indicated by an arrow.


N
SWAN CREEK
R
SWAN LAKE
300 ft
91.4 m
Marshy Area
A & B Spawning Sites
R Recording Thermometer

In 1965 the construction of a trap and fence across the stream at area A may have altered the normal spawning pattern of the fish. Eggs were numerous on gravel in area A and widely distributed on mud from the stream mouth down to area A. In 1966 area A was little used for spawning. This may, however, have been caused by the reduction in water level in 1966 such that the large proportion of the gravel bottom in this area was covered by less than 30 cm of water. Only in the lower end of area B was the current through the gravel strong enough to keep the interstices clear of mud and sand. In other areas, such as much of area A, a large proportion of the interstices are at least partially filled with mud.

Very few instances of lake trout spawning in streams have been reported in the literature. Loftus (1958) described spawning runs in the Montreal and Dog Rivers and lesser runs in the Puckasaw and Eagle Rivers, all tributary to Lake Superior. Seguin and Roussel (unpublished) described a run in Des Cedres brook, a stream flowing between Grand Lac des Cedres and Petit Lac des Cedres, Quebec. Lake trout on this run originated in both lakes, at least part of the run being outlet-spawning. This is the only other record of an outlet-spawning population. Reference to unpublished correspondence of the Alberta Department of Lands and Forests and discussions with Department personnel indicate that a small run of lake trout entered the inlet stream of Swan Lake in the period 1940-42 and probably before. Lake trout no longer appear to use this section of stream. Nets were set in the stream during the spawning season in 1965 and 1966 but no trout were taken.

It is always possible that some lake spawning may occur. However, a careful inspection of the bottom by two SCUBA divers did not

indicate the presence of any suitable areas. The high proportion of tagged fish among the mature specimens taken by anglers suggests that the number of fish not spawning in the creek would be insignificant.

Lake trout do not appear to go beyond the lower end of area B to spawn. They were never observed below this point during the spawning period nor were any eggs found. Maximum distance from the lake to the spawning site is about 400 meters. Lake trout travel a distance of approximately three km to the spawning site in the Dog River, Ontario, but only about 200 meters in the Montreal River. Total length of Des Cedres brook, Quebec, is only about 500 meters.

The depth of Swan Creek in the vicinity of the spawning area averages 30 to 50 cm. The deepest pool, just above area B, is approximately two meters deep. During the 1966 spawning period depths were some 15 to 20 cm lower. The lake trout did not spawn in depths of less than 30 cm in area A, but spawned in depths of 15 to 20 cm at the lower end of the area B. Since the current was more rapid in the latter location the selection of spawning site would seem to be affected by both depth and current.

In 1967, water flows in the late summer were very low. Debris carried from the lake, particularly lily pads, caught up on the remnants of the old dam below area A and raised the level of the stream. In this year the spawning fish were not disturbed by tagging or recovery operations. The great majority of the eggs were deposited at the lower end of area B; no eggs were found on area A.

5. <u>Time of spawning</u>

Lake trout were observed on the spawning grounds from September 22 to October 11, 1965 and September 25 to October 11, 1966. The peak

of the spawning run was October 2 to 7, 1965 and September 29 to October 5, 1966. In 1965 the water temperature was approximately 5C and in 1966 it was approximately 8C (Figure 9). Water flows, and consequently water levels in the stream, were high in 1965 and low in 1966. Despite these wide differences in physical conditions the spawning runs were at similar times and of similar duration in both years.

Martin (1957) summarized the physical conditions found during the spawning period in a number of different lakes. He found that spawning took place at temperatures of 9 - 13C, which is somewhat higher than that recorded in Swan Lake. Martin indicated a possible correlation of spawning date with meteorological conditions, such as wind and light. Dull, cold, windy weather appeared to precipitate a movement of trout on to the spawning ground whereas bright, calm, warm weather delayed or prolonged the reproductive period. These observations were substantiated by Royce (1943) in lakes in New York State. He further suggested, however, that spawning dates were closely associated with the time of the fall turn-over. Martin found that this did not hold in Ontario lakes.

No attempt has been made to assess any relationship of spawning time with meteorological observations in Swan Lake. In each of the two years overturn had already taken place before the onset of the spawning run. Data on stream spawning populations is not sufficient to suggest whether the above factors affecting the behaviour of lake-spawning populations might also be the same ones which affect stream-spawning lake trout.

6. Spawning behaviour

Spawning behaviour appeared to be similar to that reported by other authors. A few fish may remain on the spawning area during daylight

hours. Most entered the stream at dusk or soon after (seven to eight p.m.) and the peak of spawning activity occurred between nine and ten p.m. Very little activity was noted after midnight and most of the trout had returned to the lake by morning. Similar movements were reported by Martin (1957) and Loftus (1958). Seguin and Roussel (unpublished) reported that many trout remained in the stream for several days, resting during the day in a deep pool near the spawning site.

No observations were made of courtship or of the spawning act itself. The fish avoided a light when it was directed at them, making such observations very difficult. This avoidance of light is possibly the reason for the daily return to the deeper waters of the lake.

The eggs appeared to be freely scattered over the bottom with little evidence of digging. Some were laid on weeds and areas of soft mud, which does not suggest careful selection of spawning site.

F. EGGS - SURVIVAL AND DEVELOPMENT

1. Effect of substrate on survival

Following completion of spawning in 1965, 1966, and 1967 the percentage of viable eggs on different substrates was determined. Non-viable eggs became opaque and were readily separable from the viable eggs. Eggs deposited on gravel settled into crevices between the rocks, where survival ranged from 85.7 per cent to 100 per cent. Eggs deposited on a mud substrate tended to wash downstream and settle into small depressions. The percentage of viable eggs on this substrate ranged from 12.1 per cent to 100 per cent.

2. Predation

Eggs deposited on a gravel substrate and resting in the inter-

stices between the rocks were more protected than eggs deposited on mud or aquatic plants. The latter were freely exposed to predators. Observations made in December, 1966 and 1967 indicated that few of these eggs survived the first two months in the stream. No doubt many of the eggs deposited on gravel were also lost but the extent of the loss is difficult to assess. Hacker (1956) found that the lake trout in Green Lake, Wisconsin, were spawning on a smooth soft bottom and that the eggs were being eaten by mud puppies (*Necturus* sp.). Seguin and Roussel (unpublished) noted that eggs carried beyond the spawning area into a pool with a bottom of mud and debris soon died or were eaten.

The stomachs of three out of six lake trout taken by angling near the spawning area on 11 October 1965 contained lake trout eggs. Two out of four brook trout (*Salvelinus fontinalis*) taken on 15 October 1965 contained trout eggs. On the same occasion nine white suckers (*Catostomus commersoni*) were taken but none contained trout eggs. One mallard duck (*Anas platyrhynchos*) taken on 13 October, 1966, contained two lake trout eggs in its crop.

Predation of lake trout eggs by other lake trout has been reported by Royce (1951) and by DeRoche and Bond (1957) Predation by suckers has been reported by Atkinson (1931), Seguin and Roussel (unpublished) and others, but Martin (1957) reported that suckers were not a serious predator of eggs in Algonquin Park lakes. Ducks have not been previously reported as predators of lake trout eggs, but in more typical deep water spawning areas such eggs would rarely be available to them.

Greeley (1932) suggested that most of the eggs of rainbow, brown and brook trout lost to predators were 'waste' eggs that were not buried in the redd, so that the effect of predators on reproductive success

was negligible. The limited data from Swan Creek suggest that a significant number of eggs may be lost to predators, but it is difficult to assess how many of these might have died anyway, since their location is not generally one with favourable current and oxygen conditions. Lake trout do not actively dig a redd but eggs deposited on a favourable substrate soon settle into the interstices between the rocks by the action of the current.

3. Number of eggs deposited

It is difficult to compare the number of eggs deposited in 1965 and 1966 accurately, but casual observation showed that the total number was several times greater in 1965 than in 1966. The number of mature fish on the spawning area was very similar in the two years but the percentage of 'green' females recorded was significantly higher in 1966 than in 1965. These fish may have been inhibited from spawning by the higher temperatures or by the low water levels.

In 1967 water levels in the stream were maintained by debris, despite very low flows. Substantial numbers of eggs were deposited on the spawning grounds, probably comparable with those of 1965, although poor visibility made visual comparison very difficult. This observation supports the contention that it is low water levels and not low stream flows which inhibit spawning.

4. Incubation and hatching

Daly *et al.* (1962) stated that lake trout eggs normally require an incubation period of four months or more, hatching from mid-February to the end of March. The newly-hatched fry spend about a month absorbing their yolk sacs and then move into deeper water. Martin (1957) showed that in Algonquin Park lakes the incubation period varied from fifteen

to twenty-one weeks.

Temperatures in lakes may fluctuate during the incubation period and rise close to 4C. In Swan Creek, however, they remain close to 0C for a substantial portion of the time. Embody (1934) showed experimentally that the average incubation period for lake trout at 1.83C was 162.3 days. It might then be expected that the incubation period in Swan Creek would be of this order or somewhat longer. Observations on 13 December, 1966 revealed numbers of empty shells, presumably hatched, and by 1 March, 1967 viable eggs had become difficult to locate. Seguin and Roussel (unpublished), working with a stream-spawning population, first observed alevins on 7 January and reported that very few eggs remained unhatched by 3 March. In that population the spawning period lasted from October 1 - 21 with the peak of spawning activity October 5 - 13. This would suggest that conditions in a stream favour a much foreshortened incubation period.

No success was obtained in locating alevins or fry in the stream, either visually or by using an electric shocker. The stream remained partially free of ice cover all winter and it is possible that the young fish move some distance to find protection from the light.

G. FISH MOVEMENTS

Very little is known of the movements of young lake trout in their first year of life in Swan Lake. It is presumed that they move into the lake soon after hatching since use of an electric shocker has not revealed their presence in the creek during the summer. None have been taken in the lake but this may be a result of net selectivity. Royce (1951) also experienced difficulties in locating young fish in New

York lakes.

Very few data are available on the movements of adult fish in the lake. Angler's catches and the results of gill net sets indicate that the lake trout are found at all depths in the winter. In summer, lake trout are never found in the surface waters but have been taken at all other depths. Trout taken in the deepest water were predominantly aged II and III.

There have been unsubstantiated reports of lake trout observed in Swan Creek, several kilometers below the lake, at times other than spawning season. During the period June 6 to 12, 1967, lake trout weighing 500 to 1000 gm were observed at distances of up to one km from the lake. These fish appeared to move back into the lake at dusk. Stomach samples taken from specimens caught by anglers yielded *Chaoborus* larvae, of lake origin, and nymphs of stream-dwelling Plecoptera.

H. POPULATION SIZE AND ANGLING PRESSURE

1. Tagging results

During the period 21 September to 15 October 1965, 90 lake trout were tagged, using numbered plastic dart tags. One dollar was paid to anglers for the return of all tags, primarily to encourage recoveries during the winter period when no creel census station was in operation.

Since all fish were tagged during the spawning run, the population estimate obtained is an estimate of the number of mature fish in 1965. As has been previously shown, almost all mature fish are of age VI or over. An estimate of the number of these fish was obtained using formula 3.7 of Ricker (1958). The variance was calculated using

formula 3.6 and the rate of exploitation using formula 3.1. Only fish recaptured within the period 10 May to 15 October, 1966 were included; fish recaptured during the period 15 October, 1965 to 10 May, 1966 were not included since it was considered that there might be a greater likelihood of tag recoveries being reported than of untagged fish during this period of voluntary returns.

The estimate of the number of mature fish in the population, derived solely from fish recovered by angling, is 176. If all methods of recovery are included an estimate of 226 is obtained. The 95 per cent limits of confidence for these estimates are 118 to 234 and 168 to 280 respectively. It is assumed that the actual number lies somewhere betwen these two estimates, in the area of overlap of 168 to 234.

The calculation of such population estimates is justified only if certain conditions are satisfied, as outlined by Ricker (1958):
(1) that the marked fish suffer the same natural mortality as the unmarked. The tags used were of a clear plastic material so that the tag would not tend to make a marked fish any more conspicuous to predators than an unmarked fish, although it is doubtful if adult lake trout are subject to any predation other than that of man.

The application of the tags did not cause any disease in the fish. Tag wounds were inspected at the time of recovery and although complete healing over had not occurred in a number of fish, there was no sign of infection.

If there were a higher mortality in marked fish than in unmarked the population estimate obtained would be low.

(2) that the marked fish are as vulnerable to the fishing being carried on as the unmarked ones. It must be assumed that this is so, although

the differences in the population estimates obtained might suggest that fish taken in nets, as they were for tagging, are less likely to be taken in nets a second time. On this evidence the estimate obtained by angling returns would be a more accurate one.

(3) that the marked fish do not lose their mark. The adipose fin was removed from all fish tagged. One fish recovered by an angler was known to have lost its tag and two others recovered in the trammel net had lost their tags, probably while struggling in the net. Since all fish were permanently marked in this way this condition is satisfied.

(4) that the marked fish become randomly mixed with the unmarked. Since fish were tagged throughout the spawning period it is very probable that this condition is satisfied.

(5) that all marks are recognized and reported on recovery. Complete summer creel census ensured that this was so in summer. Winter returns were not used in the determination of the population estimates.

(6) that there is only a negligible amount of recruitment to the catchable population during the time the recoveries are being made. By restricting the recovery sample to only those age classes which appeared in the 1965 spawning run the possibility of recruitment to these classes is eliminated. The only possible source of error is that of accuracy in scale reading.

During May 1966 an additional seven lake trout were tagged. Recoveries of all tagged lake trout up to August 1967, totalled 37. Twenty-four fish were taken in nets at various times and subsequently released. Four, or 4.1 per cent of the total tagged, were taken in nets and retained. The number recovered by anglers was thirty-three, or 34

per cent of the original 97 trout tagged. Twenty (23.0 per cent) of the 87 lake trout sampled during the 1966 spawning run were fish tagged during the spawning run in 1965.

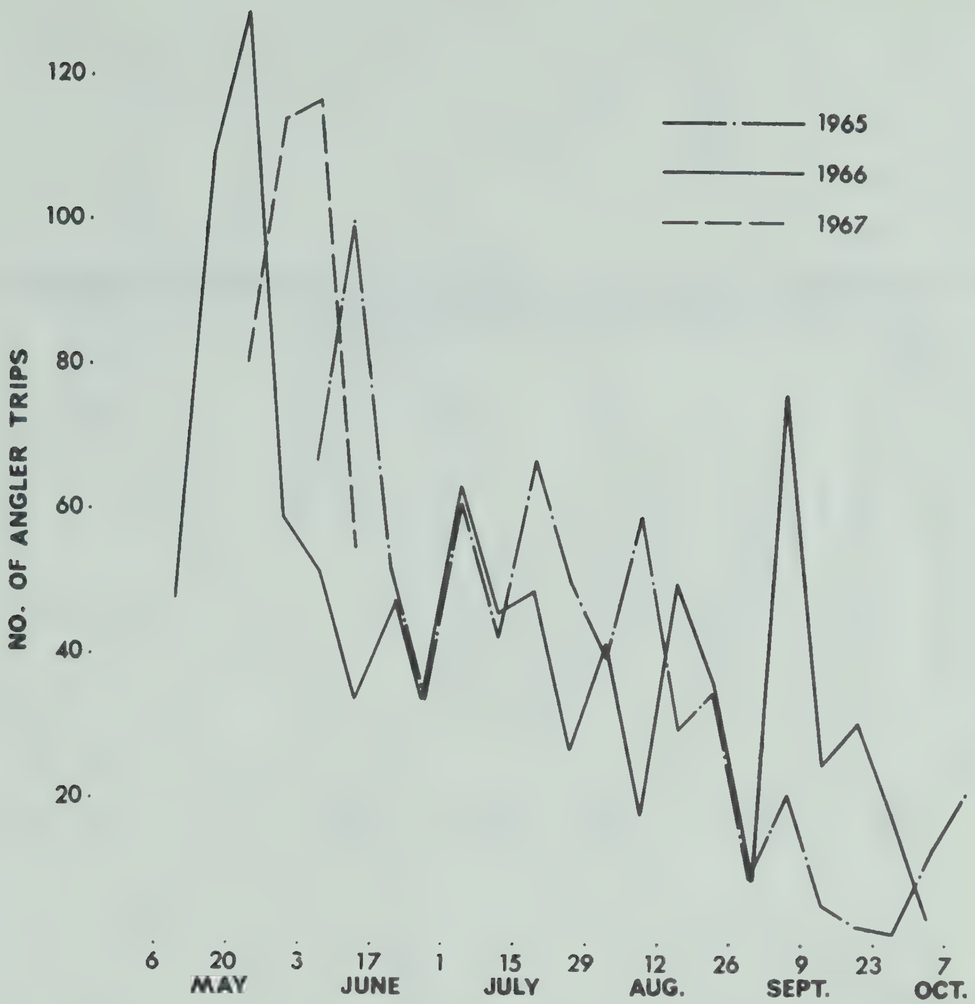
2. Angling pressure and success

It was not possible to measure winter angling pressure, although observations during a series of visits to the lake in winter showed that whenever weather conditions were not too severe there were approximately three to six parties of anglers fishing in the lake. Although voluntary creel cards were well-distributed, it was not possible to give them to every angler visiting the lake. In 1965-66, 54.4 per cent of the cards sent out were returned, but in 1966-67 the number was somewhat lower. It can, therefore, be assumed that any estimates of winter harvest are substantially lower than the actual numbers taken, even though the anglers returning the cards probably sustained a better than average success. Other studies have demonstrated that successful anglers are more likely to return creel census information than unsuccessful ones.

Although it is not possible from two years' summer creel census data to demonstrate any consistent patterns in angling pressure and catch success, there are indications of certain trends in the fishery. Figure 20 shows the changes in fishing pressure throughout the season. The highest fishing pressure is clearly recorded in the period between break-up and approximately 15 June, although the lake trout success rate may be sustained until early July (Figure 24). It is not known whether the reduction in fishing pressure is associated with increased agricultural activity at this season or a fairly consistent seasonal reduction in the catch success, or perhaps both.

Figure 20. Angling pressure at Swan Lake. The number of angler trips are plotted for each week of complete creel census. One angler-trip was recorded for each angler making a fishing trip from and return to the boat dock.

Figure 21. Mean harvest of lake trout and pike for each week of complete creel census, Swan Lake, 1965-67. The figures given are mean harvest figures for the corresponding week in each of the years in which data were collected.


NO. OF ANGLER TRIPS
120
100
80
60
40
20
1965
1966
1967
6
20
3
17
1
15
29
12
26
9
23
7
MAY
JUNE
JULY
AUG.
SEPT.
OCT.

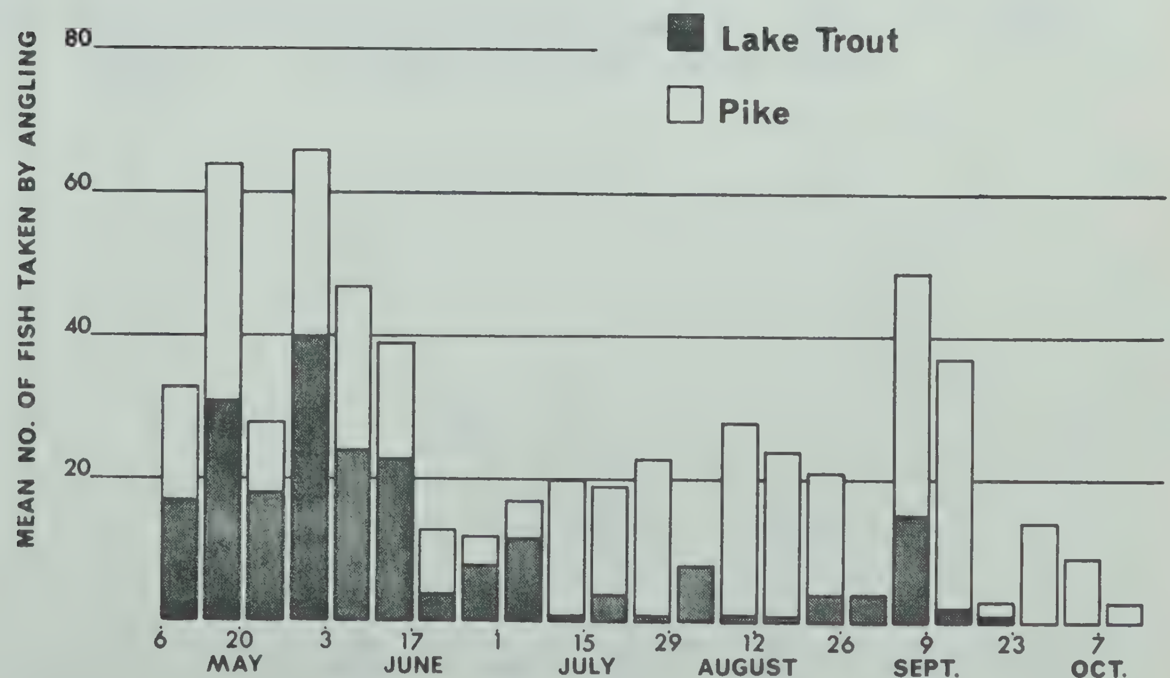
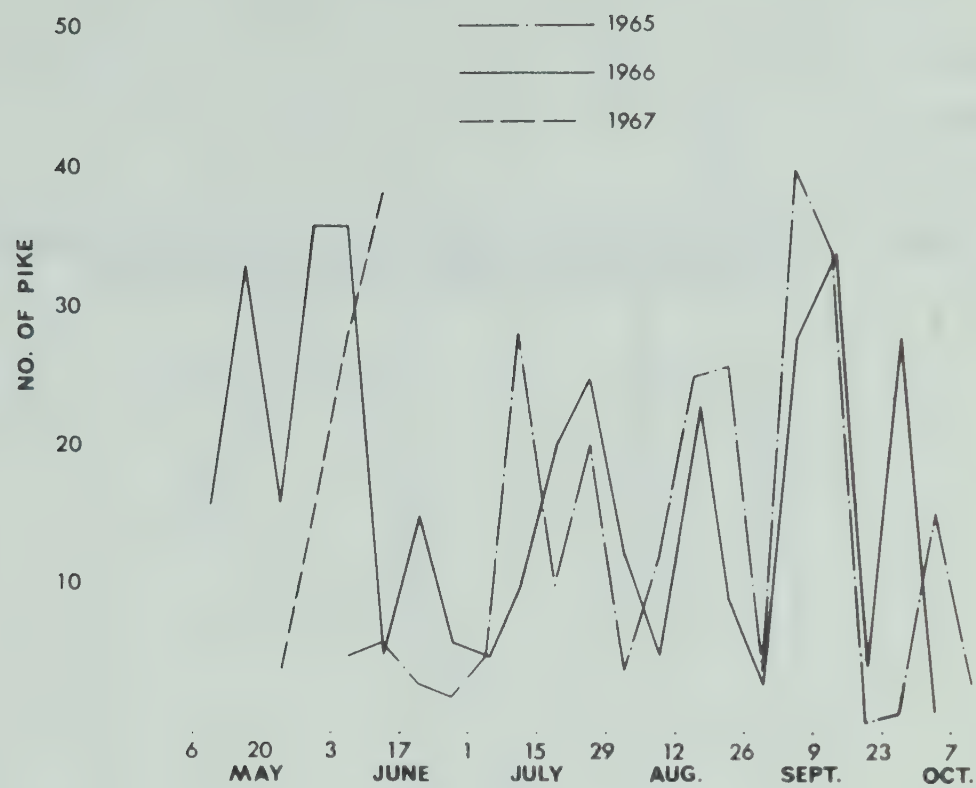
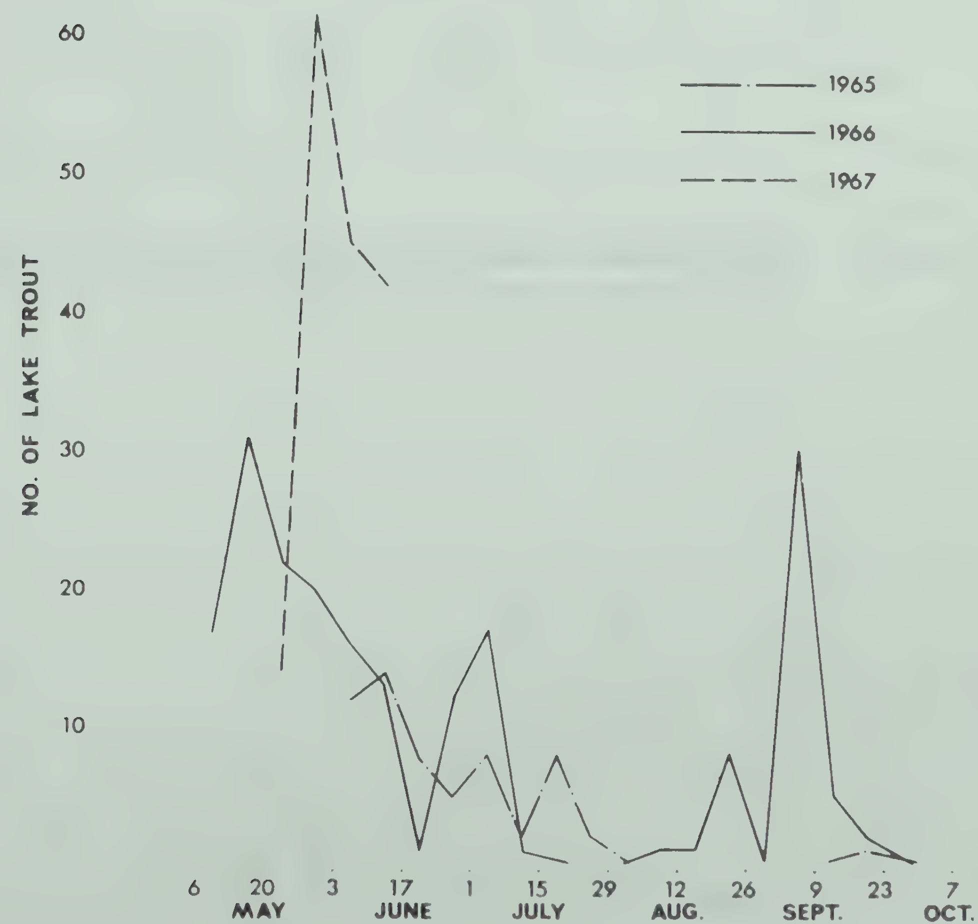

MEAN NO. OF FISH TAKEN BY ANGLING
80
60
40
20
Lake Trout
Pike
6
20
3
17
1
15
29
12
26
9
23
7
MAY
JUNE
JULY
AUGUST
SEPT.
OCT.

Figure 22. Harvest of pike by angling for each week of complete creel census, Swan Lake, 1965-67.

Figure 23. Harvest of lake trout by angling for each week of complete creel census, Swan Lake, 1965-67.



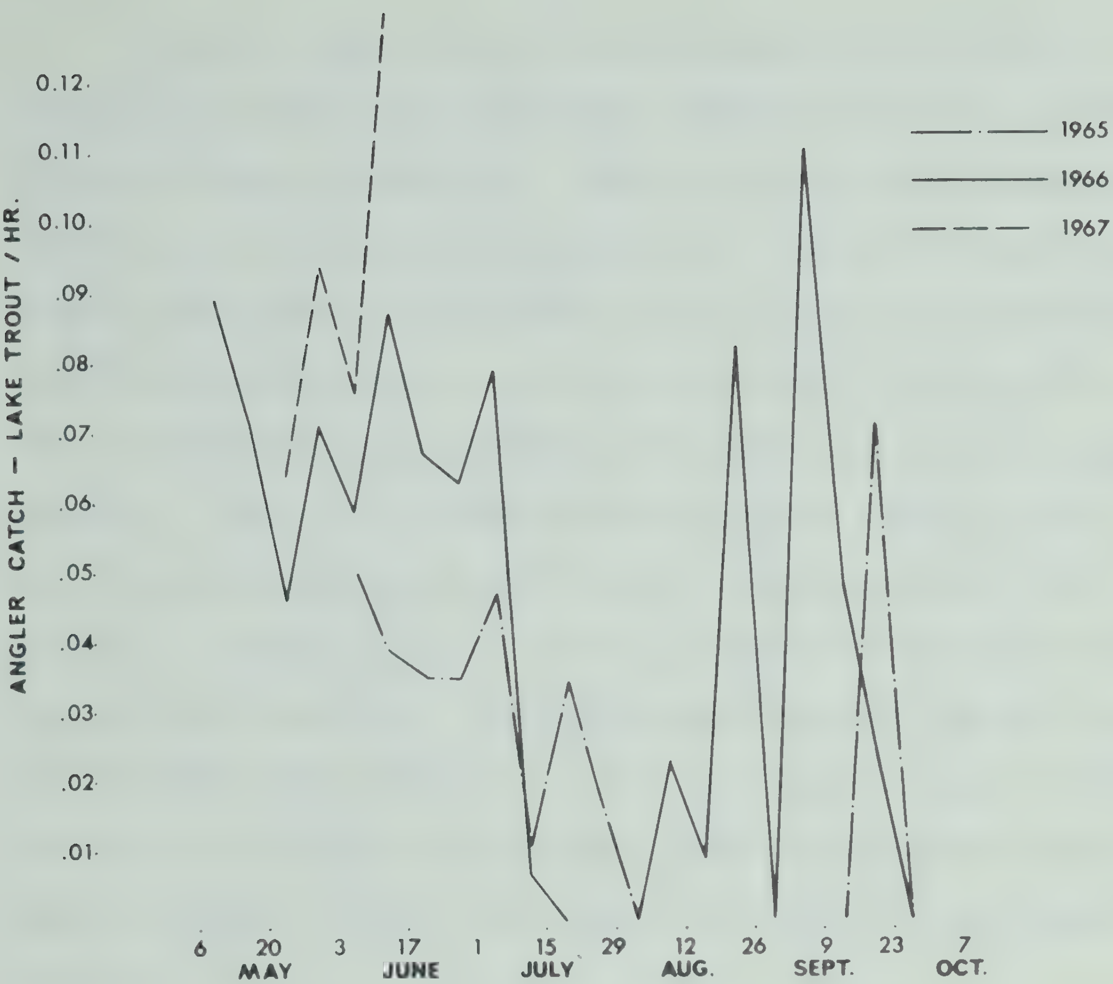
1965
1966
1967
NO. OF PIKE
50
40
30
20
10
6
20
MAY
3
17
JUNE
1
15
JULY
29
12
AUG.
26
9
SEPT.
23
7
OCT.



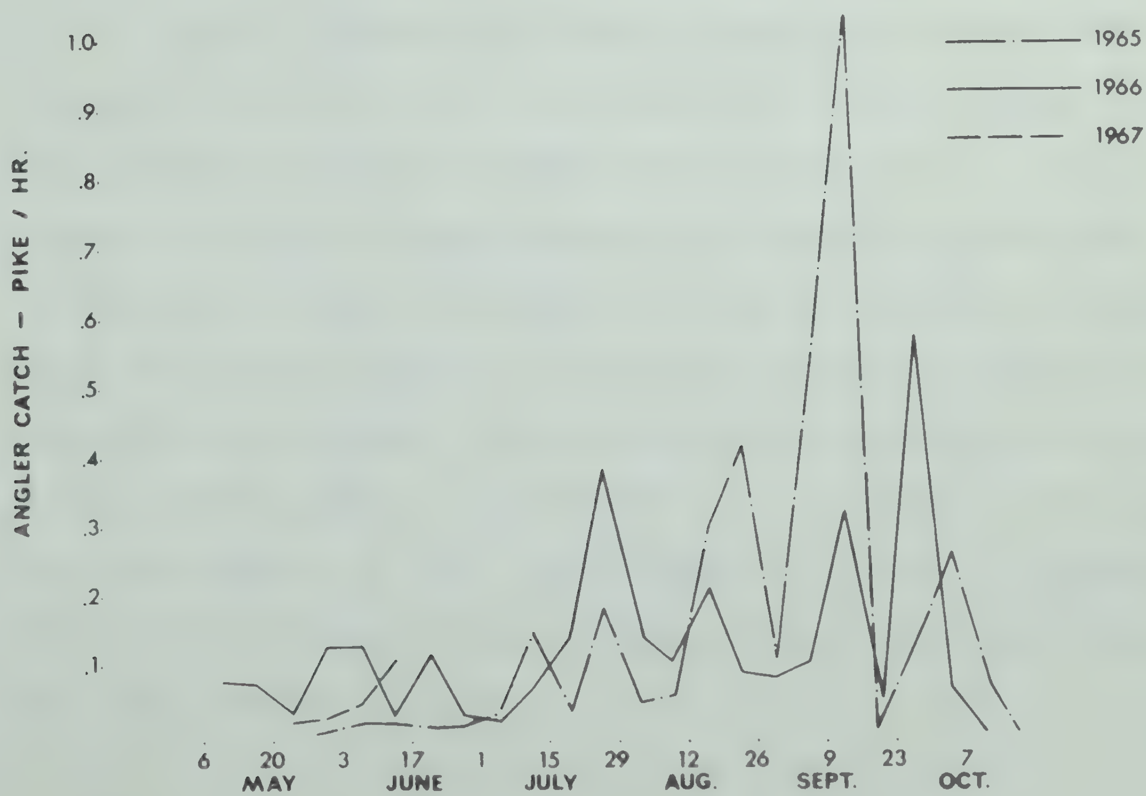
1965
1966
1967
NO. OF LAKE TROUT
60
50
40
30
20
10
6
20
MAY
3
17
JUNE
1
15
JULY
29
12
AUG.
26
9
SEPT.
23
7
OCT.

Figure 24. Mean angler catch rate for lake trout for each week of complete creel census, Swan Lake, 1965-67.

Figure 25. Mean angler catch rate for pike for each week of complete creel census, Swan Lake, 1965-67.



ANGLER CATCH — LAKE TROUT / HR.
0.12
0.11
0.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
1965
1966
1967
6
20
3
17
1
15
29
12
26
9
23
7
MAY
JUNE
JULY
AUG.
SEPT.
OCT.



ANGLER CATCH — PIKE / HR.
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
1965
1966
1967
6
20
3
17
1
15
29
12
26
9
23
7
MAY
JUNE
JULY
AUG.
SEPT.
OCT.

Prior to July 1st, and during the winter, the majority of anglers fish primarily for lake trout, although a substantial number of pike are taken incidentally. During this period both species mix freely in the relatively homothermous water. During the summer period, when the lake waters are stratified, the lake trout are restricted in their distribution and more skill may be required in locating them. Pike are restricted to the littoral waters and are more often readily available. Many of the anglers at this season are camping, often with families, and preferring the more readily available species, turn their attention to angling for pike. This is reflected in the angler catch rate for pike (Figure 25). The high success rate for lake trout in early September 1966 (Figures 21, 24) is not easy to explain; at this period in 1965 temperatures and oxygen conditions underwent some marked changes (Figures 8 and 10), but in 1966 only gradual changes were observable.

Table XV summarizes the catch of lake trout by season. The year seemed to fall naturally into three fairly distinct fishing seasons and consequently the data have been grouped in this pattern. Winter is a season of low but sustained pressure with a moderate success rate. The harvest is no doubt considerably in excess of the numbers recorded. May is the period of peak fishing activity, following ice break-up, a date which varies somewhat from year to year but which is generally early in May. Angling success is moderate but the total harvest for the period quite high (Figures 21, 23). June to October is a season of low trout harvest with very little fishing pressure exerted on the species during that period (Figure 20).

TABLE XV. Yield of lake trout and pike by angling - Swan Lake, 1965-67.

	No. of angler trips recorded	No. of fish taken	No. lake trout taken	Total weight lake trout (kg)	Av. weight lake trout (kg)	Yield lake trout (kg/ha)	No. pike taken	Total weight pike (kg)	Av. weight pike (kg)	Yield pike (kg/ha)
June - Oct. 1965	706	231	56	89.4	1.60	0.454	175	146.3	0.87	0.743
Nov. 1965 - April 1966	109	84*	84	112.6	1.54	0.571	*			
May 1966	339	188	86	148.5	1.73	0.754	102	82.2	0.89	0.417
June - Oct. 1966	688	367	112	116.6	1.04	0.592	255	126.1	1.03	0.643
Nov. 1966 - April 1967	85	69*	69	68.9	1.08	0.348	*			
May 1967	124	87	66	82.5	1.25	0.419	21	20.2	0.96	1.103
June 1965 - May 1966	1154	503	226	350.5	1.55	1.78	277	228.5	0.88	1.160
June 1966 - May 1967	897	523	247	268.0	1.08	1.36	276	146.3	0.53	0.740

*No record of pike catch in winter.

A moderate rate of angling success for this lake is 0.05 fish per hour or 20 hours per fish (Figure 24). It is evident by the many hours expended on this species that it is considered a trophy fish and that many hours spent in its quest are justified.

3. Angling methods

Lake trout are taken by trolling either a lure or a small dead fish during the open water season. In winter small fish, frozen or preserved, are used almost exclusively.

4. Effect of angling

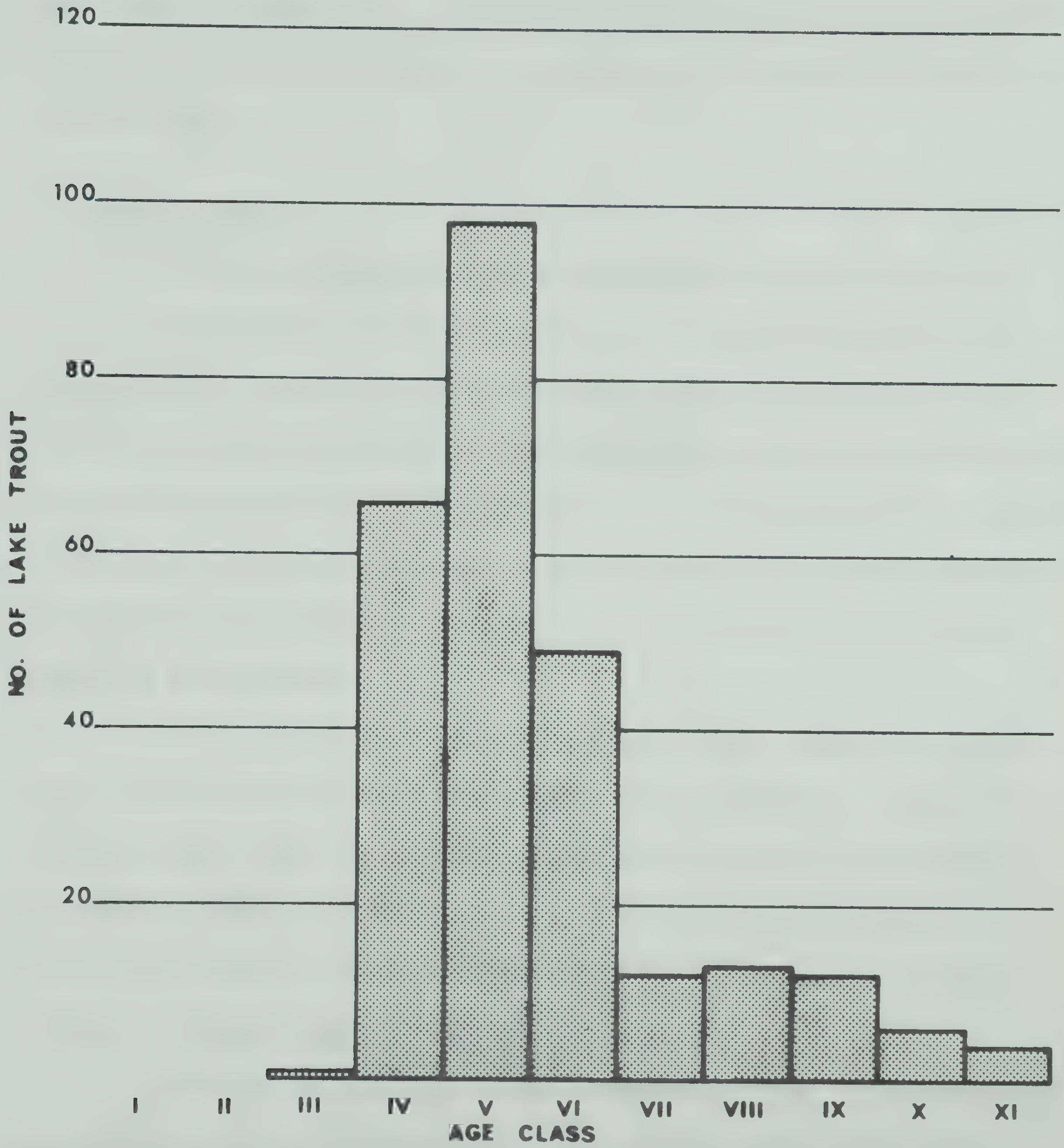
The age class distribution of lake trout taken by angling during the periods of complete creel census (Figure 26) illustrates that the majority of fish taken are in age classes IV to VI. 35.4 per cent of the fish taken were mature (aged VI and over).

To measure the effect of angling upon the lake trout population it is necessary to compare annual harvest with recruitment. This can be done by considering the population of mature fish in Swan Lake only. Since it has been shown (Figure 15) that almost all the lake trout first mature at age VI, it is reasonable to use the relative number of six-year-old fish in the spawning population as a measure of recruitment to this segment of the population. The number of tagged fish recovered by anglers during a one-year period following tagging provides a measure of the annual harvest of mature fish.

During the 1965 and 1966 spawning runs 25.3 per cent and 20.7 per cent respectively of the fish sampled were six-year-olds. The harvest by angling of mature fish tagged in 1965 was 26 fish within one year, or 28.9 per cent. Since this figure exceeds the recruitment it can be

deduced that angling is having a deleterious effect upon the population. While this figure is based upon only one year's angling returns, and harvest probably fluctuates from year to year, it does provide an indication that a problem exists and some suggestion of its magnitude.

Figure 26. Distribution of age classes of lake trout taken by angling during the periods of complete creel census, Swan Lake, 1965-66.


120
100
80
60
40
20
NO. OF LAKE TROUT
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
AGE CLASS

X. THE PIKE POPULATION

1. Introduction

The pike is the only other species of fish present in significant numbers in Swan Lake. It is therefore necessary to examine certain aspects of its natural history to determine its role in the ecology of the lake trout.

2. Age and Growth

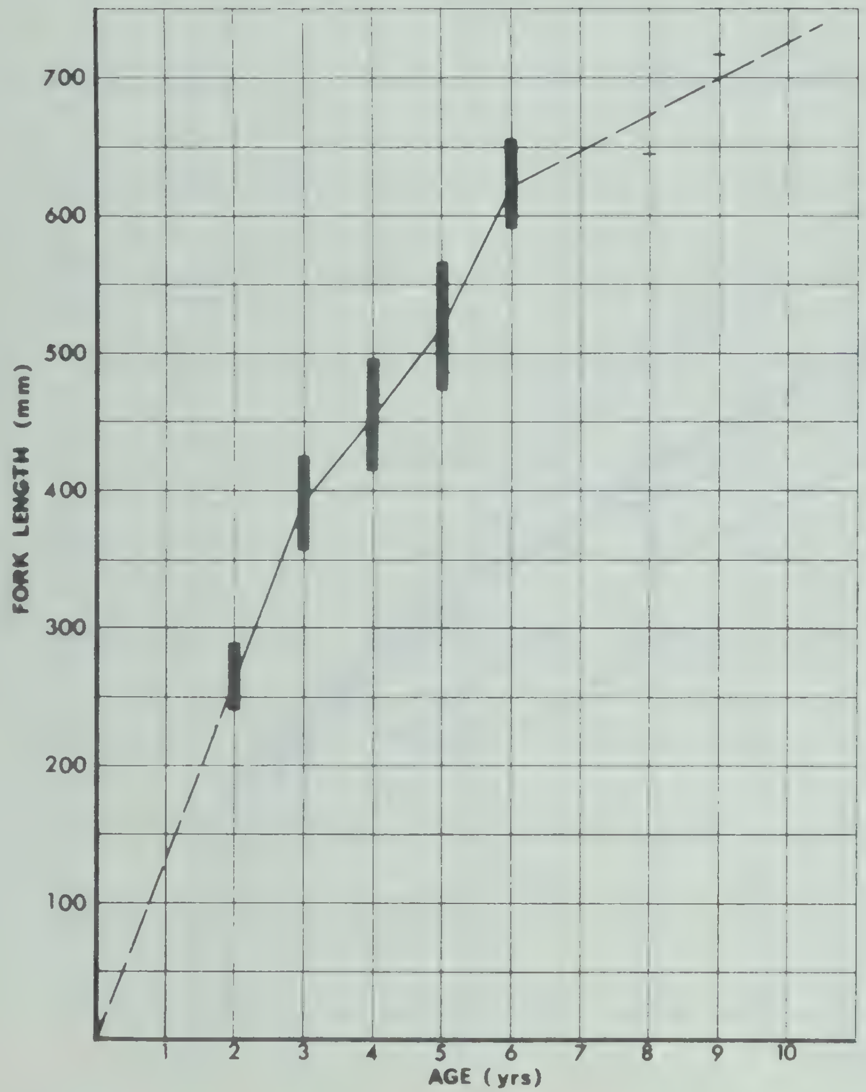
The scale method was used in aging pike taken from Swan Lake.

The growth rate of Swan Lake pike is shown in Figure 27. In preparing this curve, only fish collected during the period May 1 to June 15 were used. The figures used should then approximate the lengths of the fish at the time of annulus formation. Formation of the annulus is normally completed by the end of May and most of the year's growth, as reflected in the scale growth, takes place between that time and the beginning of September.

It is of note that there is a broad length range for each age class in Swan Lake. Toner (1966) summarized the work of a number of authors to show that, in general, female pike grow faster than males. The growth rates of the two sexes have not been plotted separately in the current study but such an observation may well explain the broad overlap in lengths between adjacent year classes.

In Figure 28 the growth rate of Swan Lake fish is compared with that from four other selected areas. The data for this figure were extracted from Carlander (1953). Two of the curves are composite growth curves of pike from a selected area (Minnesota and Manitoba). It is evident that the growth rate of pike in Swan Lake compares favourably

Figure 27. Relationship of length and weight in Swan Lake pike with age. The heavy bars represent the standard deviation of the parameter from the mean.


FORK LENGTH (mm)
700
600
500
400
300
200
100
1
2
3
4
5
6
7
8
9
10
AGE (yrs)

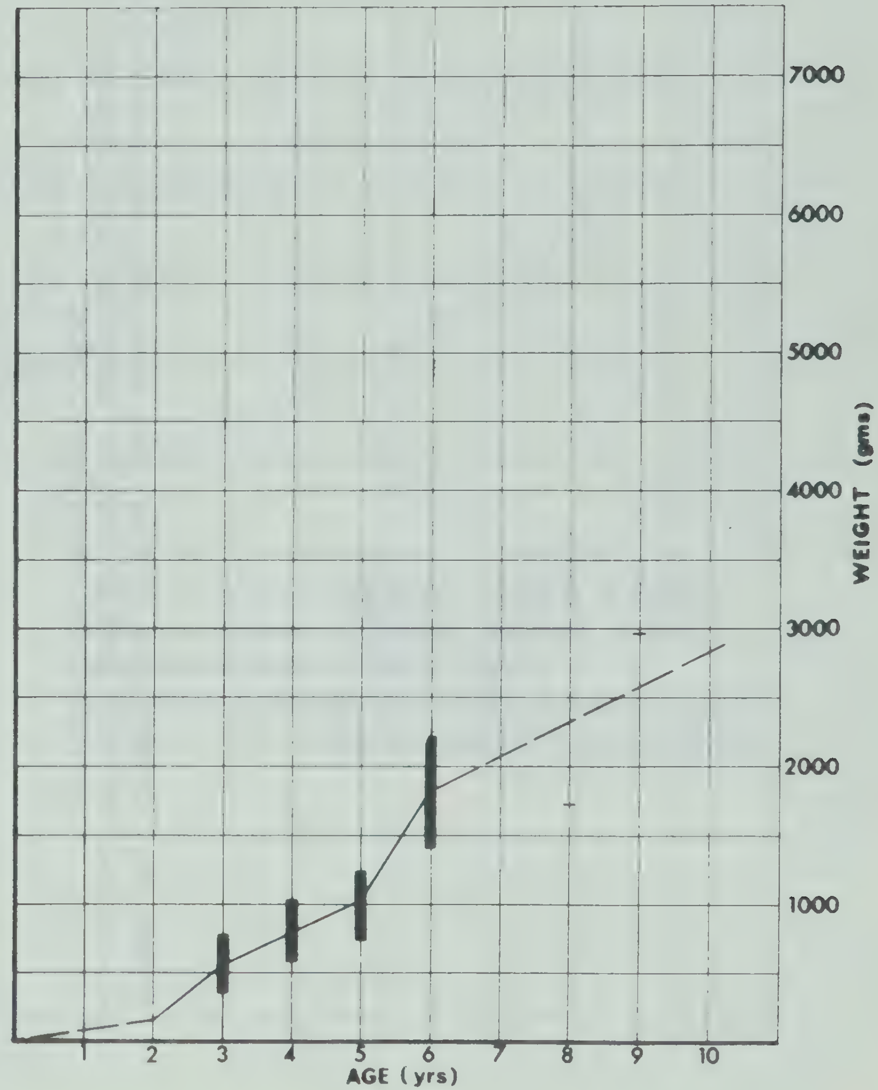
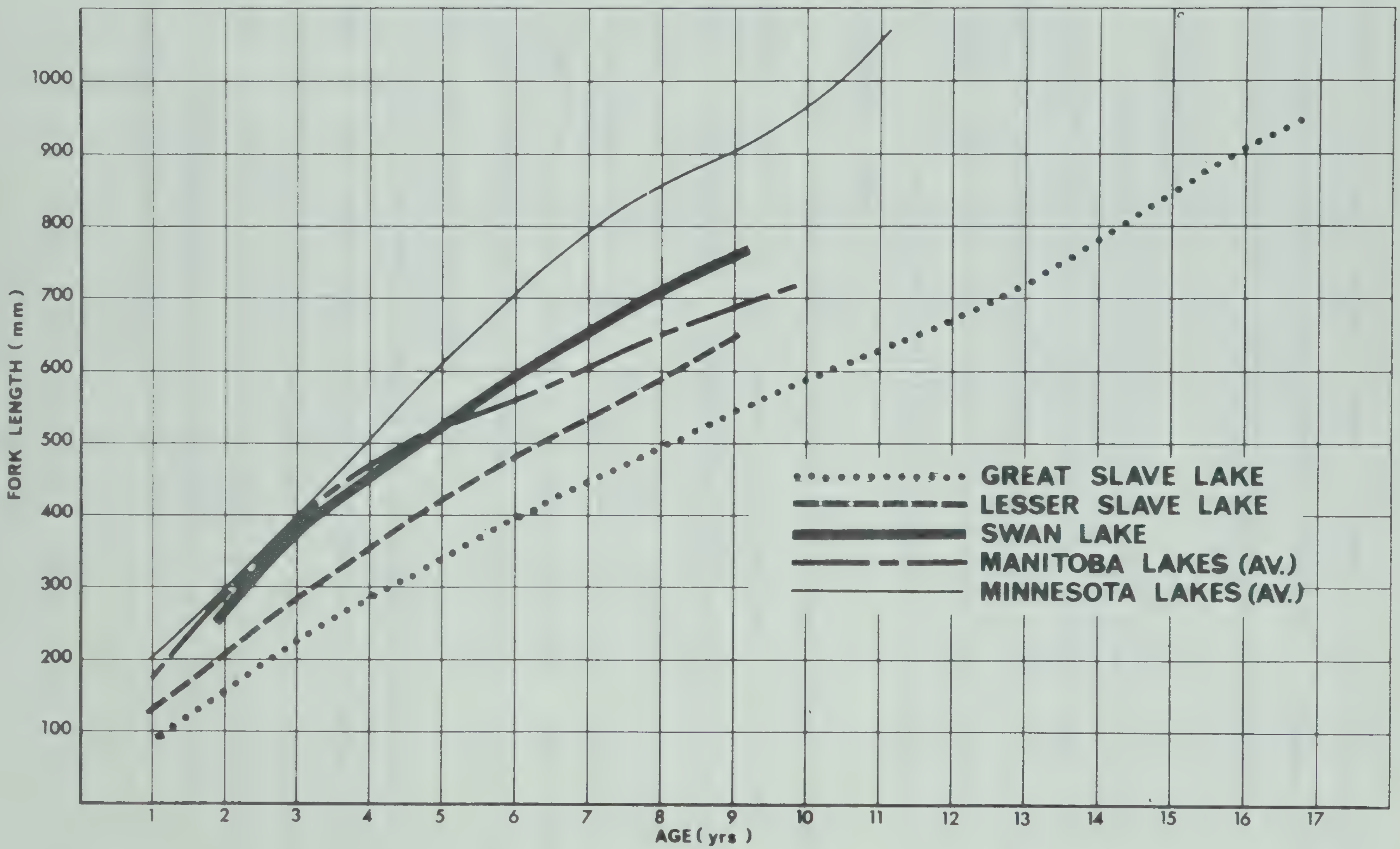

WEIGHT (gms)
7000
6000
5000
4000
3000
2000
1000
1
2
3
4
5
6
7
8
9
10
AGE (yrs)

Figure 28. Growth rate of pike from Swan Lake compared with that of pike from four other selected lakes or areas. Data extracted from Carlander (1953).


GREAT SLAVE LAKE
LESSER SLAVE LAKE
SWAN LAKE
MANITOBA LAKES (AV.)
MINNESOTA LAKES (AV.)
FORK LENGTH (mm)
AGE (yrs)

with that of the more northerly waters of Great and Lesser Slave Lakes and is similar to growth rates observed in Manitoba. A somewhat faster growth rate is observed in the more southerly lakes of Minnesota.

3. Feeding habits

The method of collection and analysis of stomach sample data from pike was very similar to that employed for the lake trout. The results are used to indicate the food preferences of the pike according to season (Table XVII) and by length classes (Table XVI). Changes in feeding habits are no doubt related to variations in the availability of individual items.

It is evident from the tables that amphipods (primarily *Gammarus lacustris)* constitute a major proportion of the diet at all seasons. Odonata, Hirudinea and, to a lesser extent, Ephemeroptera and Trichoptera are other major constituents. It is evident from Table XVI that fish are found mainly in the diet of larger pike. Most of the fish found in the stomach contents are young pike or young lake trout. Other studies have shown that pike are, by preference, piscivorous (Buss, 196; Threinen *et al.*, 1966; Hunt, 1965; Lawler, 1965).

Most of the data on feeding habits covers the period May to October and very few data are available for the period November to April. During the latter period water temperatures are relatively uniform and the fish are widely distributed in the lake. During this period young trout are undoubtedly available to the pike and it is possible that significant numbers are taken.

TABLE XVI. Stomach contents of Swan Lake pike showing variation by length classes 1965-66

	200-299		300-399		400-499		500-599		600-699		700-799		TOTAL	
	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Volume
No. of stomachs	11		16		150		55		13		2		247	
% empty stomachs	9.1		12.5		19.3		30,9		53.8		100.0		23.5	
FOOD ITEM														
Fish	10.0	3.8	7.1	59.1	2.5	67.2	7.9	72.7	33.3	100.0	-	-	5.3	68.3
Crustacea														
Amphipoda	70.0	84.1	92.8	75.6	93.4	48.3	84.2	56.7	50.0	78.2	-	-	88.9	54.0
Cladocera	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Insecta														
Hemiptera	-	--	-	-	0.9	100.0	2.6	9.3	-	-	-	-	1.1	54.7
Coleoptera	10.0	100.0	7.1	2.6	10.7	40.3	26.3	17.1	-	-	-	-	13.2	31.9
Odonata	30.0	6.2	35.7	43.8	27.3	25.3	50.0	30.2	33.3	48.3	-	-	32.8	28.1
Trichoptera	-	-	7.1	0.5	13.2	1.6	7.9	4.5	-	-	-	-	10.6	2.0
Ephemeroptera	20.0	21.0	14.2	16.6	13.2	1.5	26.3	9.1	16.6	3.6	-	-	16.4	6.3
Diptera (misc.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaoborinae	-	-	-	-	-	-	2.6	41.7	-	-	-	-	0.5	41.7
Chironomidae	10.0	0.7	7.1	n.m.	1.6	n.m.	5.3	4.3	-	-	-	-	3.1	1.6
Hirudinea	20.0	15.1	21.4	3.1	24.7	32.9	44.7	27.6	16.6	3.6	-	-	28.0	28.3
Mollusca	-	-	7.1	7.2	9.9	0.3	2.6	1.1	-	-	-	-	7.4	0.9
Nematomorpha	30.0	43.3	-	-	2.5	11.4	-	-	-	-	-	-	3.2	27.4
Plant Material	20.0	2.5	14.2	21.7	23.1	17.3	34.2	7.8	-	-	-	-	23.8	14.1
Unidentified	-	-	-	-	1.6	26.4	5.3	8.4	50.0	20.6	-	-	2.7	18.8
Aves	-	-	-	-	-	-	2.6	100.0	-	-	-	-	0.5	100.0

n.m. - not measurable

TABLE XVII. Stomach contents of Swan Lake pike showing seasonal variation 1965-66

	MONTH													
	MAY		JUNE		JULY		AUGUST		SEPT		OCTOBER -APRIL		TOTAL	
	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Vol. in Sample	% Occurrence	Mean % Volume
No. of stomachs	68		45		46		34		24		6		223	
% empty stomachs	23.5		8.9		34.8		26.5		54.2		0		26	
FOOD ITEM														
Fish	3.8	79.6	2.4	3.8	10.0	42.7	-	-	36.4	97.9	16.7	33.6	6.7	65.1
Crustacea														
Amphipida	92.3	78.4	95.1	57.8	83.3	41.9	76.0	76.6	63.6	93.0	50.0	52.5	85.5	66.2
Cladocera	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Insecta														
Hemiptera	4.2	59.3	4.9	15.9	-	-	-	-	-	-	-	-	2.4	37.6
Coleoptera	6.3	24.8	9.7	29.4	46.7	20.4	12.0	74.8	-	-	16.7	8.0	15.2	28.4
Odonata	27.1	20.3	53.7	30.1	53.3	28.3	36.0	38.9	18.2	7.8	-	-	37.6	28.1
Trichoptera	29.2	3.8	7.3	0.7	3-3	1-3	12.0	0.2	-	-	-	-	12.7	2.7
Ephemeroptera	29.2	0.4	36.6	13.0	10.0	0.3	-	-	-	-	-	-	19.4	6.1
Diptera (Misc.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaoborinae	-	-	4.9	23.2	3.3	n.m.	-	-	-	-	-	-	1.8	15.5
Chironomidae	-	-	14.6	1.4	-	-	-	-	-	-	-	-	3.6	1.4
Hirudinea	20.8	15.6	41.5	30.6	56.7	39.8	36.0	16.7	9.1	20.0	-	-	32.7	28.2
Mollusca	12.5	3.4	7.3	2.0	-	-	20.0	2.3	-	-	-	-	8.4	2.7
Nematomorpha	4.2	15.5	7.3	0.6	3.3	100.0	4.0	n.m.	9.1	n.m.	-	-	4.8	16.4
Plant Material	29.2	20.1	21.9	9.6	30.0	9.7	32.0	6.2	18.2	10.8	-	-	30.3	10.5
Unidentified	2.1	50.0	7.3	28.1	3.3	15.9	12.0	54.2	-	-	83.3	80.1	7.9	54.9
Aves	-	-	-	-	-	-	4.0	100.0	-	-	-	-	0.6	100.0

n.m. - not measurable

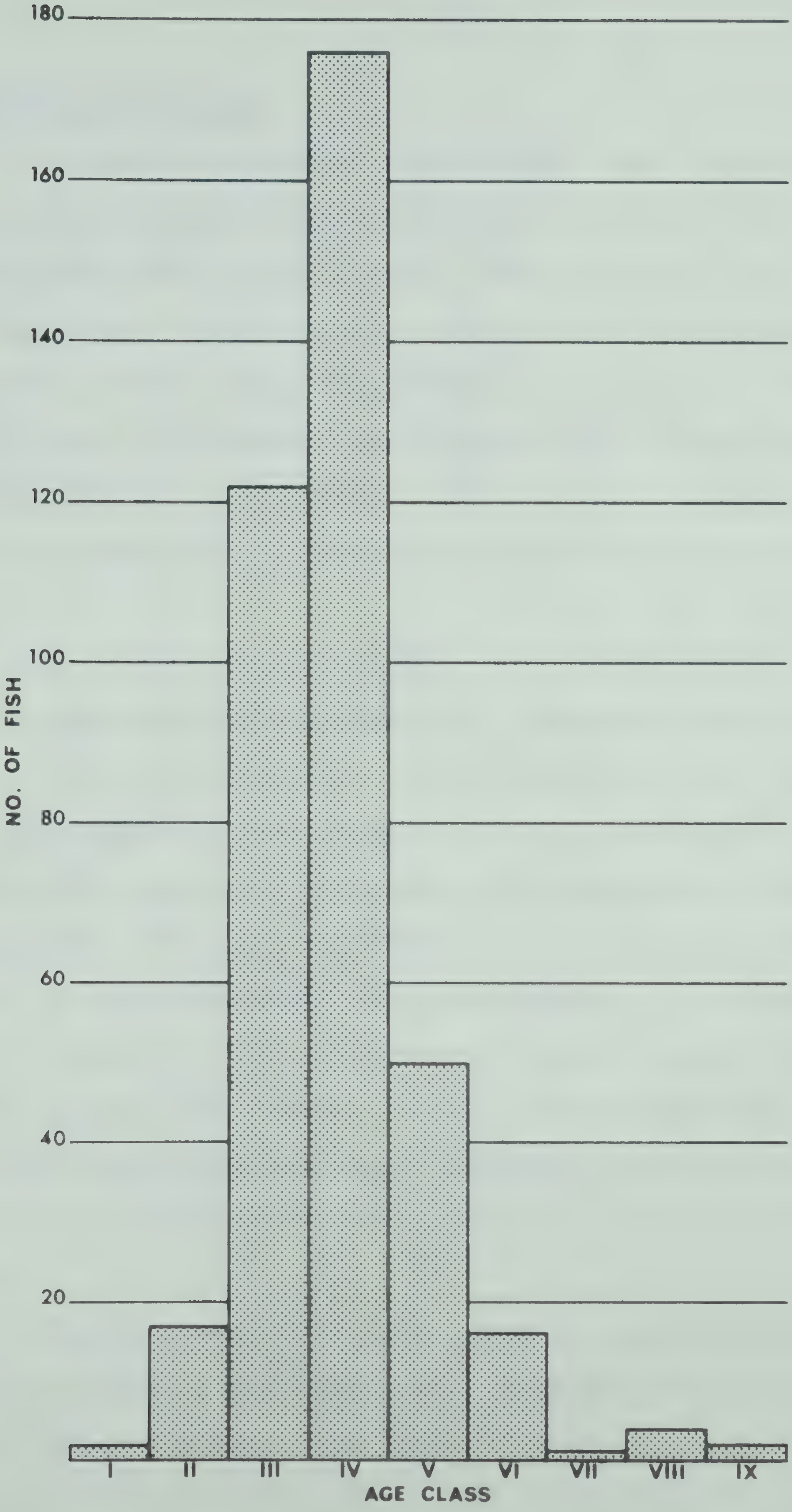
4. Population size and angling pressure

Two pike were tagged during the period of the lake trout spawning run in 1965. An additional 36 pike were tagged in May and June, 1966. Prior to June, 1967, 15 of these (39.5 per cent) were recovered, 14 (36.8 per cent) by angling, 12 of them within one year of the date of tagging. All of these fish were aged III or over and were large enough to be immediately available to the angler. Seasonal fluctuations in the harvest of pike are illustrated in Figures 21 and 22, and in Table XV.

Figure 29 shows the distribution of age classes of pike taken by angling. These results indicate the presence of only small numbers of fish of year classes V and over. They may, however, not provide a true picture of the age class distribution, since older fish may be more difficult to catch. The evidence suggests that angling pressure is sufficiently heavy to remove most of the pike before they reach age VI and a very substantial proportion before they reach age V. While angler harvest of pike can be quite efficient (Threinen *et al.*, 1966), it is doubtful if angling is having any deleterious effect upon the pike population in Swan Lake. It is probable that the harvest could be greatly increased without any serious harm to the population.

It would be difficult to obtain a valid population estimate from the tagging returns obtained, since many of the returns were received during the period November to April, a period when total harvest records are almost non-existent. If this period were eliminated from the calculations the sample size would be too small to be of significance.

Figure 29. Distribution of age classes of pike taken by angling, Swan Lake, 1965-66.


180
160
140
120
100
80
60
40
20
NO. OF FISH
I
II
III
IV
V
VI
VII
VIII
IX
AGE CLASS

XI. DISCUSSION

1. Limnology of Swan Lake

The terms 'oligotrophic' and 'eutrophic' have long been used in limnology to describe the extremes of lake productivity. Each term describes lakes which possess a number of broad characteristics. The term 'mesotrophic' has more recently appeared in the limnological literature to describe lakes lying between the two extremes. The characteristics of oligotrophic and eutrophic lakes have been summarized by Welch (1952) and by Reid (1961). Certain of these characteristics are shown in Table XVIII, together with related observations from Swan Lake.

It is evident from this summary that Swan Lake possesses many of the characteristics of a eutrophic lake. There are several features, however, which are not completely typical of eutrophic lakes. The lake is only moderately shallow and the littoral zone moderate in extent. The dissolved oxygen in the hypolimnion, while significantly depleted during periods of thermal stratification, is still present in sufficient quantity to support salmonids, and winter stagnation is relatively slight. The concentration of electrolytes is not as high as that found in many eutrophic lakes (300-500 ppm), nor is the transparency as low. These facts suggest that Swan Lake is mesotrophic in nature, but that the balance of the characteristics are closer to eutrophy than oligotrophy.

The composition of the phytoplankton has been used by several authors as a means of classifying lakes. Hutchinson (1967) listed a series of dominant plankton types ranging from oligotrophy to eutrophy.

TABLE XVIII. Relation of some limnological characteristics of Swan Lake to those of the accepted lake types.

Characteristic	Oligotrophic Lakes	Eutrophic Lakes	Swan Lake
Max. depth	Deep	Shallow	Moderately shallow - 11.6 m
Mean depth	Deep	Shallow	6.16 m
Volume of hypolimnion	Large	Minimal or absent	Relatively small
Temperature of hypolimnion	Close to 4C	Above 4C if present	9 - 11C
Electrolytes	Low	High	Relatively high
Transparency	High	Low	Relatively low
Humic materials	Low	High	Moderate
Dissolved oxygen	High at all seasons	Minimal or absent in hypolimnion	Low in hypolimnion
Littoral zone	Limited	Extensive	Fairly extensive
Littoral vegetation	Sparse	Dense	Moderate
Profundal fauna	Varied-dominated by *Calopsectra* (=Tanytarsus)	Limited-dominated by *Chironomus*	Limited-dominated by *Chironomus*
Presence of *Chaoborus*	Generally absent	Present	Present-large population
Plankton	Quantitatively restricted. 'Blooms' rare. Chlorophyceae dominant	Quantitatively abundant. 'Blooms' common. Myxophyceae and diatoms dominant	Quantitatively 'Blooms' common. Myxophyceae and diatoms dominant

In this he considers dominants such as *Asterionella* and *Ceratium* to be characteristic of eutrophic conditions. He states that cyanophytes such as *Aphanizomenon* and *Anabaena* are generally found only in eutrophic waters. Rawson (1956) summarized the algal types characteristic of lakes in western Canada. In Table XIX the dominant phytoplankters in Swan Lake are compared with those found by Rawson along with his designation of approximate trophic distribution. This comparison suggests that Swan Lake could be better classified as mesotrophic and does, in fact, possess some oligotrophic characteristics.

Another factor of significance is the presence of a substantial population of *Chaoborus flavicans* in Swan Lake. Larvae of the genus *Chaoborus* are generally scarce in the hypolimnion of lakes having little oxygen depletion (Stahl 1966). *Chaoborus flavicans* is most commonly found in holomictic lakes, which fall into Hutchinson's class II category (Hutchinson, 1957).

A consideration of all the above factors suggests that Swan Lake should be considered as mesotrophic. It is perhaps closer to the eutrophic condition than the oligotrophic and is best described as 'late mesotrophic.'

2. The lake trout

Lake trout are confined at their southern limits to deep cool (oligotrophic) lakes (Lindsey, 1964). It is reasonable to assume that when lake trout first invaded Swan Lake (probably following the retreat of the Wisconsin ice-sheet) it was a deep cool lake. By the natural processes of aging, the character of the lake has changed and it is currently mesotrophic in nature. It is of interest then, to determine

TABLE XIX. The dominant limnetic algae of Swan Lake and their relation to trophic status. Phytoplankters associated with trophic level in Western Canada lakes are taken from Rawson (1956).

Trophic status	Phytoplankter	Swan L. Phytoplankter
Oligotrophic	*Asterionella formosa*	*Asterionella formosa*
	Melosira islandica	
	Tabellaria fenestrata	
	Tabellaria flocculosa	
	Dinobryon divergens	*Dinobryon sertularia*
	Fragilaria capucina	
	Stephanodiscus niagarae	
	Staurastrum spp.	
	Melosira granulata	
Mesotrophic	*Fragilaria crotonensis*	*Fragilaria crotonensis*
	Ceratium hirundinella	*Ceratium hirundinella*
	Pediastrum boryanum	
	Pediastrum duplex	
	Coelosphaerium naegelianum	*Coelosphaerium Kuetzingianum*
	Anabaena spp.	*Anabaena circinalis*
	Aphanizomenon flos-aquae	*Aphanizomenon flos-aquae*
	Microcystis aeruginosa	
Eutrophic	*Microcystis flos-aquae*	

the extent to which this population of lake trout has adapted to the change in conditions and what effect current conditions may be exerting upon the survival of the population.

(i) growth rate:

The growth rate of Swan Lake trout is rapid compared with that of other populations. It is exceeded by that in Upper Waterton Lake, particularly in older age classes. This is probably a direct result of the absence of forage fish in Swan Lake. Larger fish may need to expend considerable energy in the collection of sufficient *Chaoborus* larvae to satisfy their needs, far greater than would be required to catch forage fish of equivalent nutritive value.

(ii) age and size at maturity:

The majority of Swan Lake trout mature at age VI. There is evidence that maturity in lake trout is roughly correlated with growth rate and size of fish. Fish in slower growing populations mature at a greater age. The relatively early maturity in this population is associated with the rapid growth rate. The relative uniformity in age of maturity is a result of the relative uniformity in the growth rates of individuals in an age class.

(iii) relationship of diet and taxonomic characters:

The pyloric caecum counts from Swan Lake trout are clearly divergent from the means for the species given by other authors and from the Cold Lake sample. Since pyloric caeca do have a digestive function (Lagler, Bardach and Miller, 1962) and since the purely planktonivorous diet of these trout seems to be unique for the species it is possible that some causal relationship exists.

Significant differences between the numbers and lengths of gill rakers in the Cold Lake and Swan Lake populations do not in themselves prove any relationship between these characters and diet. It is, however, reasonable to assume that a planktonivorous fish would benefit from an increased number of longer rakers which would thereby increase its straining efficiency. This is borne out by the large numbers of long gill rakers found in planktonivorous species such as the kokanee (*Oncorhynchus nerka* Walbaum) and the cisco (*Coregonus artedii* LeSueur).

The existence of these differences is at least suggestive that some adaptive selection has taken place in response to the unique diet of this population. The extent of variation throughout the range of the species has not been adequately demonstrated and it is suggested that to minimise this source of error further work should be concentrated in lake trout populations of the western prairie area.

The wider range in gill raker lengths in the Cold Lake sample suggests that wider variation may be found where a structure serves a less significant function.

(iv) feeding habits:

Lake trout are versatile feeders, with forage fish as preferred items. Since in most lakes they are restricted to the hypolimnion for a part of the year their diet is probably restricted more by availability than selectivity.

In Swan Lake, *Chaoborus* larvae are a readily available source of food. However, they occupy a less significant portion of the diet in winter. At this time, when the lake is homothermous, the lake trout can readily enter the littoral zone and obtain amphipods and ephemeropterans

not available to them at other seasons.

The fact that trout are taken successfully in this lake by angling with frozen or preserved minnows indicates that they will readily eat fish when it is available. Martin (1966) described lake trout populations in Ontario which could only obtain access to forage fish for a part of the year; when these were not available the trout became planktonivorous. Redick (1967) states that some lakes in Alaska contain only lake trout; in these lakes the most common food items are clams of the family Sphaeriidae.

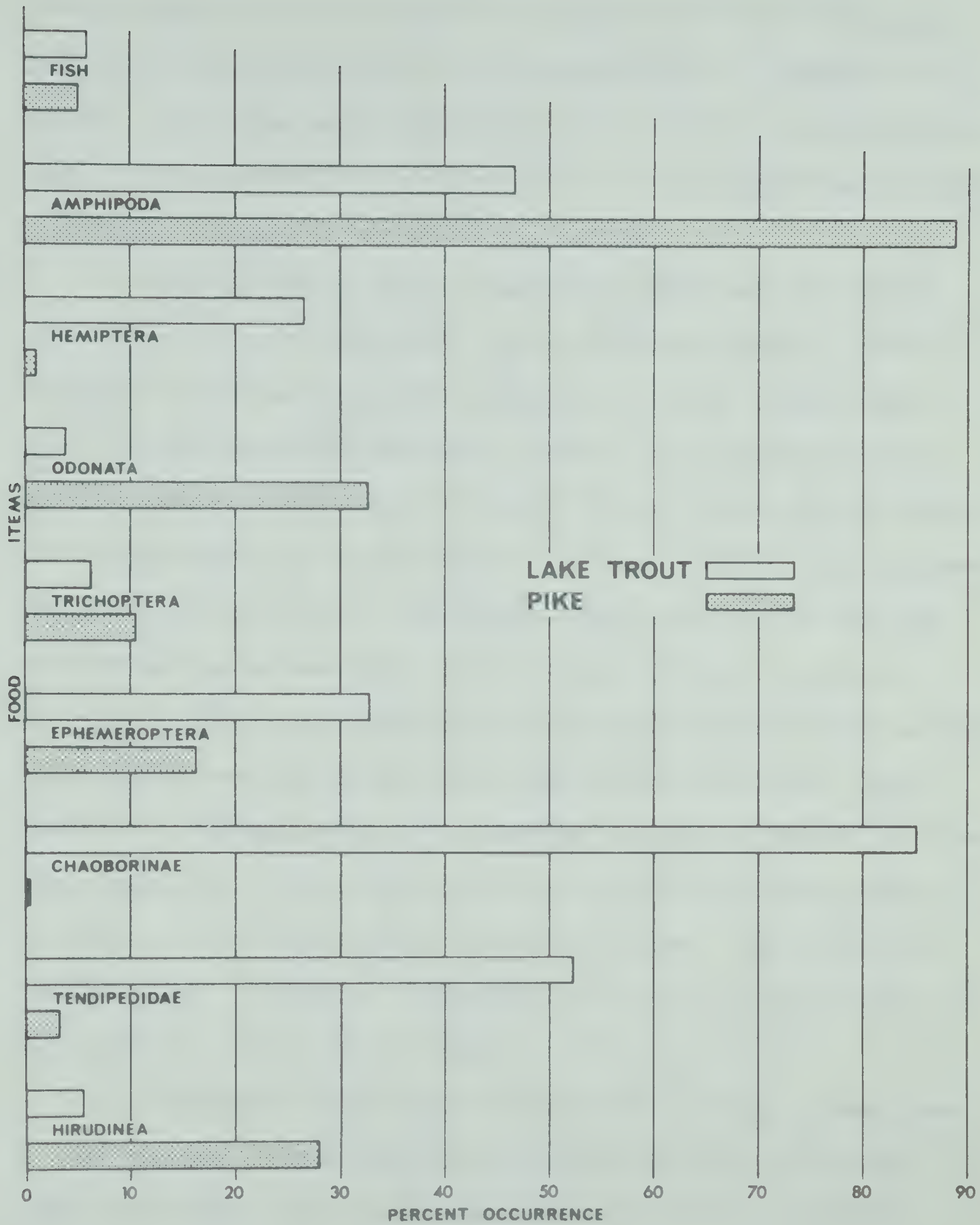
In Figure 30 the diets of the lake trout and the pike are compared. From this it is evident that there is relatively little competition for food; only in the Amphipoda and Ephemeroptera is there any significant area of common harvest and there is little evidence to suggest an excessive harvest of either of these groups. It is doubtful that food supply is at any time a limiting factor for either of these two species of fish in this lake.

(v) reproduction:

The consistency with which lake trout spawn close to a certain date in given lakes suggests that photoperiodism may be significant in determining spawning time. The two seasons of observation at Swan Lake substantiate this view, since the spawning run occurred at almost the same time in the two years, despite marked differences in water temperature. There is evidence, however, that other physical factors, including temperature, may affect the length of the run.

Egg deposition was observed in the three years 1965-67, under quite different conditions of water level and flow in the outlet stream.

Figure 30. Relative occurrence of food items in the diets of lake trout and pike, Swan Lake, 1965-66.


FISH
AMPHIPODA
HEMIPTERA
ODONATA
TRICHOPTERA
EPHEMEROPTERA
CHAOBORINAE
TENDIPEDIDAE
HIRUDINEA
FOOD ITEMS
LAKE TROUT
PIKE
0
10
20
30
40
50
60
70
80
90
PERCENT OCCURRENCE

The high deposition in 1965 and 1967, compared with that of 1966, suggests that low water levels in the stream may inhibit spawning to some degree. Since flows were exceptionally low in 1967, but egg deposition high, it is concluded that low flow *per se* does not significantly affect deposition, although it may affect egg survival.

Hatching time in lakes is generally consistent for a given lake and most eggs hatch within a two to three week period. Data collected in the current study and by Seguin and Roussel (unpublished), both on stream spawning populations, indicate a very broad hatching period extending from December to March. Since for most of this period the stream temperature is consistent at between 0 and 1C it is suggested that the critical period is that between egg deposition and the time that stream temperatures drop to their winter minimum. During this period of higher temperatures accelerated incubation of the egg can take place and the hatching period can be significantly shortened. Eggs deposited at the beginning of the spawning run will be exposed to higher temperatures for a longer period of time and may hatch significantly earlier than those deposited at the end of the run. Seguin (personal communication) is currently investigating this problem in an attempt to determine the validity of the theory.

The quantity of suitable substrate for spawning in Swan Creek is very limited. It is essential for successful survival that the rubble be of such a size as to permit the eggs to drop between and receive protection from predators and light. It is also essential that the water percolate between the rubble to provide adequate aeration for the eggs and freedom from silt. The area of the bottom of Swan Creek

containing this type of substrate is limited to little more than 100 square meters. It is not clear as a result of this study what carrying capacity such an area might have and whether it would be sufficient to sustain the maximum population of lake trout in this lake. It would appear, however, that for this trout population to depend entirely upon an area so small is putting its future existence in a very tenuous position. Any improvement in extent and quality of spawning area would reduce the danger of extinction and probably raise the potential of the population to produce larger year classes under favourable conditions. The year class structure of the population does not exhibit any serious fluctuations. This indicates a relatively stable level of production, but it is not known whether this may be optimal or maximal for the lake.

An attempt was made in 1963 to establish a new spawning area in the lake by adding rubble to the lake bottom but examination of the area selected suggests that the site was poorly chosen. If a new spawning area were to be established in the lake it should be located in the west end of the lake where the substrate is relatively firm. A site adjacent to the inlet stream would be preferred. As an alternative measure, improvements to the outlet stream could be made, using either the present stream channel or a separate spawning channel. Rocks would have to be imported and some measures taken to prevent siltation. Some work of this type is being carried out in Des Cedres Brook, Quebec. The success of the project will be assessed in the next few years.

The remainder of an old beaver dam in Swan Creek has stabilised water levels in the creek for many years. It has maintained water levels over the spawning area, even during periods of low flow, and may, as a

result, have prevented severe fluctuations in spawning success. Its partial erosion in 1965 exposed the creek to more serious fluctuations in level but the accumulations of debris at the site may quickly reduce this problem. To provide greater stability of stream water level it is suggested that a low dam could be constructed at the site, which would be of a more permanent nature and not subject to erosion during high water flows.

The loss of eggs to predators is not considered to be a serious one. Eggs lost in this way have generally been deposited in a poor location and so remain exposed to view. If more suitable spawning areas were provided the losses immediately following deposition would be significantly reduced.

(vi) angler harvest:

Creel census results show that many hours may have to be spent to obtain one lake trout by angling. There are many verbal reports of substantial catches taken 10 to 20 years ago; undoubtedly the advent of good road access has permitted increased fishing pressure and resulted in a much lower return per angler. It is probable that a fairly consistent year-round fishing pressure has resulted in a larger total harvest.

The results of the tagging experiment indicate a total adult population of about 200 fish. Of these, some 34 per cent were recovered by angling in a period of 18 months. Figure 18 indicates that mortality of mature fish is high, although natural mortality is not separated from angler harvest. The results indicate that angler harvest of mature fish may significantly exceed the recruitment of this segment of the population. If angler harvest were to continue at the present rate, it would very soon seriously reduce the population of mature fish. It

would seem probable that in fact the population has been reduced from previously higher levels. How low the population would drop before the angling pressure dropped significantly is open to conjecture, but since angling for younger age classes would no doubt continue the older age classes would be still exposed to angling pressure.

Since this study provides no information on mortality rates in the younger age classes, it is difficult to estimate how many adults are necessary to maintain the present population. Since, however, the attraction of this fishery lies in the possibility of taking a fish weighing in the order of 3000 to 5000 gms, an attempt should be made to maintain as large a population as possible of adult fish. As has been shown in other studies, and as is illustrated by the tagging returns, lake trout are relatively vulnerable to angling. Some degree of protection by regulation is, therefore, necessary.

The establishment of a minimum size limit is not justified since there is no reason why a harvest of younger age classes should not be made. Reduced catch limits would also serve little purpose, since only occasionally are several fish taken by one angler. The most satisfactory form of protection would be complete closure of the lake for a part of the year. This measure would, of necessity, eliminate the recreational harvest of pike for a portion of the year, but pike are only the prime targets of anglers during the period July to September; at other times they are taken as a second preference or incidentally during lake trout fishing. It is therefore recommended that as a preliminary measure the lake be closed to angling for the period of January 15 to June 1. Subsequent creel census and sampling would be necessary to determine whether this measure was having the desired effect.

A reduction of about 50 per cent of the present harvest of lake trout could be predicted from Table XV, but it is not possible to estimate the extent to which angling pressure during the open period of the year might change as a result of the restriction and what effect this might have on total harvest.

The present study indicates several areas which would warrant further research. Amongst these are:

a) The relationship of diet to variability in certain taxonomic characters. Extensive sampling of several populations in the western prairie area would be necessary.

b) The factors affecting spawning behaviour in a stream-spawning population.

c) The effects of changes in stream condition upon egg deposition in a stream-spawning population.

d) The effects of stream water temperatures upon hatching time in a stream-spawning population.

e) The early life history and movements of the lake trout in Swan Lake.

f) The suitability of Swan Lake stock for introduction to other waters of a mesotrophic nature where suitable spawning conditions exist.

XII. CONCLUSIONS

1. Swan Lake is limnologically mesotrophic. Since lake trout commonly occur in oligotrophic waters the lake offers conditions which are atypical for the species.
2. The abundance of food in Swan Lake permits a rapid growth rate but the absence of a forage fish species limits the growth rate of older age classes.
3. There is an indication of adaptive selection in both gill rakers and pyloric caeca correlated with the unique diet of this population. More work on other western populations would be necessary to substantiate this.
4. The diet of the lake trout is primarily governed by availability and a wide variety of food items is taken when available. During any given feeding period, however, lake trout do tend to be selective for a given preferred food item.

   There is no evidence to suggest that availability of food is a limiting factor for either the trout or pike populations.
5. The extent of egg deposition during spawning may be affected by depth of water over the spawning area but does not appear to be affected by the normal fluctuations in flow.
6. The hatching period extends from December to March. Actual hatching time for a given egg may depend upon the number of degree-days in which the stream temperature exceeds 0C.
7. The spawning area used by the Swan Lake trout is very limited. It is not known whether the lake could support a larger population of trout if the area were improved. Improvement would, however, put the

present population in a less tenuous position.

8. The population of mature lake trout is about 200. Angler harvest is high and a reduction in harvest is proposed if the quality of the fishery is to be maintained or improved. A closed season from January 15th to June 1st is proposed.

9. The pike in Swan Lake are ecologically separated from the lake trout in summer. At other seasons the two species appear to mix freely but the degree of interaction has not been established.

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XIV. APPENDICES

APPENDIX I

PARTIAL LIST OF BIRDS SEEN AT SWAN LAKE

Common loon *(Gavia immer)*

Canada goose *(Branta canadensis)*

Mallard *(Anas platyrhynchos)*

Shoveller *(Spatula clypeata)*

Redhead *(Aythya americana)*

Lesser scaup *(Aythya affinis)*

Bufflehead *(Bucephala albeola)*

Goldeneye *(Bucephala clangula)*

White winged scoter *(Melanitta deglandi)*

Ruddy duck *(Oxyura jamaicensis)*

Eared grebe *(Podiceps caspicus)*

Red necked grebe *(Podiceps grisegana)*

Sandhill crane *(Grus canadensis)*

American bittern *(Botaurus lentiginosus)*

Greater yellowlegs *(Totanus melanoleucus)*

Spotted sandpiper *(Actitis macularia)*

Osprey *(Pandion haliaetus)*

Common nighthawk *(Chordeiles minor)*

Ruffed grouse *(Bonasa umbellus)*

Yellow shafted flicker *(Colaptes auratus)*

Downy woodpecker *(Dendrocopos pubescens)*

Raven *(Corvus corax)*

Gray jay *(Perisoreus canadensis)*

American dipper *(Cinclus mexicanus)*

Oregon junco *(Junco oregnus)*

APPENDIX II

TEMPERATURE READINGS - STATION I (1965)

DATE - 1965	May 19	June 5	June 7	June 10	June 14	June 18	June 21	July 5	July 10	July 12	July 16	July 20	July 24	July 26	July 30
Temperature °C															
Air	4.0	23.3						23.0							
Surface	7.7	12.3	11.0	14.9	15.2	13.4	12.2	18.2	13.9	13.0	15.0	16.2	17.7	18.2	20.4
5 ft (1.5m)	7.2	12.2	11.0	13.2	14.5	13.3	12.0	15.3	13.8	12.8	13.9	16.0	16.5	17.2	18.0
10 ft (3.05m)	6.3	11.9	10.6	11.4	12.6	12.3	11.9	12.5	12.3	12.5	12.0	13.5	14.2	14.7	15.2
15 ft (4.6m)	6.2	9.3	10.6	10.5	11.1	10.4	11.7	11.1	11.2	10.5	10.3	11.6	12.5	11.5	11.5
20 ft (6.1m)	6.2	8.9	9.7	9.0	9.9	10.0	10.2	9.9	10.2	10.0	9.7	10.0	10.3	10.2	10.2
25 ft (7.6m)	6.0	8.4	8.2	7.9	8.5	9.4	9.5	9.4	9.4	9.5	9.0	9.5	9.4	9.5	9.7
30 ft (9.1m)	6.0	7.6	7.4	7.6	8.0	9.0	9.1	9.0	8.9	9.0	8.9	9.3	9.1	9.0	9.3
35 ft (10.7m)	6.0	7.2	7.2	7.5	7.8	8.7	8.0	8.7	8.5	8.7	8.8	9.0	9.0	9.0	9.1

APPENDIX II (cont'd)

TEMPERATURE READINGS - STATION I (1965)

DATE - 1965	Aug 2	Aug 6	Aug 9	Aug 13	Aug 16	Aug 18	Aug 27	Aug 30	Sept 3	Sept 6	Sept 11	Sept 13	Sept 27	Oct 9
Temperature °C														
Air													8.7	10.0
Surface	22.4	19.4	20.7	17.9	17.9	18.2	17.2	14.0	13.0	12.5	10.6	10.0	8.2	7.3
5 ft (1.5m)	19.7	19.0	20.2	17.9	17.5	17.4	17.0	14.0	13.0	11.7	10.5	10.5	6.7	7.3
10 ft (3.05m)	14.5	14.9	15.9	17.8	16.0	16.5	16.7	13.9	13.0	11.5	10.5	10.0	6.7	7.1
15 ft (4.6m)	12.2	12.3	12.2	11.8	15.5	13.4	13.6	13.6	12.5	11.5	10.5	10.0	6.5	7.0
20 ft (6.1m)	11.0	10.5	10.5	11.6	11.2	11.2	11.2	11.9	11.5	10.7	10.0	9.8	6.4	6.9
25 ft (7.6m)	10.1	9.7	9.8	10.5	10.0	10.1	10.3	10.4	10.8	10.0	9.5	9.5	6.3	6.8
30 ft (9.1m)	9.5	9.3	9.4	9.9	9.7	9.8	9.2	9.7	9.9	9.5	9.3	9.0	5.6	6.7
35 ft (10.7m)	9.0	9.0	9.1	9.4	9.3	9.3	9.1	9.3	9.5	9.1	7.8	7.5	5.0	6.7

APPENDIX III

TEMPERATURE READINGS - STATION II (1965)

DATE - 1965	June 14	June 21	July 5	July 12	July 20	July 26	Aug 2	Aug 9	Aug 16	Aug 18	Aug 27	Aug 31	Sept 6	Sept 13	Sept 29	Oct 12
Temperature °C																
Air			18.8												12.3	10.6
Surface	14.8	12.2	18.6	12.4	16.5	18.8	22.0	21.2	17.8	18.3	17.7	15.0	12.5	10.3	7.5	7.1
5 ft (1.5m)	14.0	12.2	17.7	11.2	15.3	18.6	19.6	19.6	17.7	17.7	17.7	13.7	11.5	9.7	6.7	6.9
10 ft (3.05m)	13.5	11.5	12.1	10.4	13.9	18.4	16.1	17.9	16.5	16.8	17.7	13.6	11.4	9.6	6.5	6.6
15 ft (4.6m)	12.5	11.2	10.3	10.3	11.9	13.0	12.0	12.8	14.7	14.8	17.5	13.0	11.2	9.5	6.0	6.5
20 ft (6.1m)	10.5	10.5	9.7	9.2	9.5	10.5	10.0	10.0	10.5	10.9	11.2	11.1	8.9	8.5	4.8	4.8

APPENDIX IV

TEMPERATURE READINGS - STATION III (1965)

DATE - 1965	June 14	June 21	July 5	July 12	July 20	July 26	Aug 2	Aug 9	Aug 16	Aug 18	Aug 27	Aug 31	Sept 6	Sept 29
Temperature °C														
Air			19.8											12.3
Surface	14.9	12.2	16.6	13.0	16.0	17.9	22.7	19.8	17.5	18.5	17.3	16.5	12.6	7.7
5 ft (1.5m)	14.7	12.0	13.8	13.0	15.9	17.0	20.1	19.0	17.3	17.3	17.1	14.0	11.8	6.7
10 ft (3.05m)	12.5	12.0	12.1	12.8	13.0	13.2	15.6	14.5	16.3	17.1	16.0	13.7	11.5	6.5
15 ft (4.6m)	10.6	11.8	10.7	12.0	11.2	11.4	12.0	12.9	13.4	13.3	13.2	13.6	11.5	6.5
20 ft (6.1m)	10.4	9.2	10.0	10.6	11.0	11.0	10.6	10.9	11.1	11.0	11.4	12.1	10.7	6.4
25 ft (7.6m)	10.0	8.7	9.3	9.7	10.5	10.4	9.6	10.0	10.0	10.4	10.5	10.0	10.0	6.0
30 ft (9.1m)	9.4	8.2	8.8	9.3	9.3	9.6	9.1	9.2	9.5	9.9	9.7	9.5	9.5	5.5
35 ft (10.7m)	7.8	8.0	8.5	8.9	9.0	9.2	9.1	9.0	9.4	9.3	9.1	9.4	9.0	5.2

APPENDIX V

TEMPERATURE READINGS - STATION I (1966)

DATE - 1966	May 13	May 24	May 27	June 4	June 6	June 10	June 13	June 15	June 18	June 21	June 24	June 28	June 30
Temperature °C													
Air	9.2	11.8	14.2	9.0	11.6	13.1	16.2	19.4	16.2	16.2	14.6	15.4	13.6
Surface	7.2	8.7	11.0	11.8	11.7	12.6	13.1	14.3	14.7	15.0	14.9	15.3	15.4
5 ft (1.5m)	7.1	8.4	10.9	11.7	11.6	12.6	12.8	14.2	14.6	14.8	14.8	15.3	15.4
10 ft (3.05m)	6.8	8.3	10.8	11.7	11.4	12.5	12.5	13.1	14.4	14.6	14.8	15.2	15.2
15 ft (4.6m)	6.5	8.2	9.2	11.6	11.0	11.4	12.2	12.6	13.7	13.8	14.6	14.2	15.0
20 ft (6.1m)	6.1	8.2	8.9	9.1	10.4	10.3	11.1	12.2	11.0	13.0	12.6	12.4	14.1
25 ft (7.6m)	5.5	8.0	8.6	8.6	8.4	9.1	9.0	11.3	9.1	10.4	10.2	11.0	11.4
30 ft (9.1m)	4.9	8.0	8.4	8.4	8.1	8.7	8.5	10.1	8.7	9.1	9.0	9.4	9.2
35 ft (10.7m)	4.8	7.6	7.9	7.9	7.9	8.2	8.3	9.0	8.5	8.6	8.6	8.8	8.9

APPENDIX V (cont'd)

TEMPERATURE READINGS - STATION I (1966)

DATE - 1966	July 2	July 4	July 8	July 12	July 15	July 20	July 22	July 25	July 28	July 31	Aug 2	Aug 5	Aug 9
Temperature °C													
Air	15.0	13.3	14.1	14.6	21.0	17.6	17.2	12.4	15.6	16.2	21.9	14.2	20.3
Surface	15.2	14.4	16.5	15.8	17.2	17.7	17.2	16.3	17.0	16.8	18.8	17.6	17.0
5 ft (1.5m)	15.2	14.4	16.5	15.7	16.8	17.4	16.7	15.8	16.3	16.8	17.6	17.7	16.4
10 ft (3.05m)	15.2	14.3	15.8	14.6	15.0	17.2	16.6	15.8	15.9	16.7	17.1	17.7	16.0
15 ft (4.6m)	15.2	13.1	13.2	13.2	13.2	13.8	14.5	14.4	14.3	14.4	15.2	15.0	14.5
20 ft (6.1m)	13.8	12.2	12.4	12.0	11.5	12.4	12.5	12.6	12.6	13.3	13.1	13.6	12.9
25 ft (7.6m)	11.5	11.2	11.4	11.0	10.8	11.8	11.5	11.2	11.4	11.1	11.2	11.7	11.7
30 ft (9.1m)	9.4	10.4	10.6	10.3	10.1	10.9	10.6	10.4	10.4	10.6	10.6	11.2	10.8
35 ft (10.7m)	9.0	9.0	10.2	8.0	8.9	10.3	10.3	9.8	9.4	9.7	9.7	10.4	10.3

APPENDIX V (cont'd)

TEMPERATURE READINGS - STATION I (1966)

DATE - 1966	Aug 12	Aug 16	Aug 19	Aug 25	Aug 30	Sept 2	Sept 6	Sept 10	Sept 12	Sept 17	Sept 25	Sept 30	Oct 5	Oct 12
Temperature °C														
Air	15.0	13.7	10.8	-	-	14.1	17.9	15.3	16.7	13.2	10.6	16.9	12.1	0.9
Surface	15.1	15.2	14.1	16.9	14.0	14.3	15.5	15.2	14.9	14.1	12.9	12.2	11.1	8.9
5 ft (1.5m)	15.1	15.3	14.2	16.5	14.4	14.2	15.4	15.1	14.5	14.1	12.9	11.9	11.1	8.9
10 ft (3.05m)	15.0	15.3	14.2	15.1	14.4	14.2	13.8	14.7	14.5	14.0	12.9	11.9	11.0	8.9
15 ft (4.6m)	14.5	13.6	14.1	14.1	13.2	13.9	13.2	13.7	13.6	13.7	12.9	11.8	10.7	8.9
20 ft (6.1m)	12.9	12.7	12.6	13.0	12.6	12.5	12.6	13.0	12.8	13.0	12.8	11.7	10.7	8.8
25 ft (7.6m)	11.6	11.9	12.0	11.8	11.8	11.7	11.7	12.1	12.0	12.4	12.1	11.7	10.5	8.7
30 ft (9.1m)	10.9	10.8	11.0	11.3	11.2	11.4	11.2	11.6	11.4	11.8	11.9	11.6	10.2	8.7
35 ft (10.7m)	10.5	10.6	10.6	10.8	10.8	10.9	10.9	11.1	11.1	11.5	11.5	9.7	8.6	8.5

APPENDIX VI

TEMPERATURE READINGS - MISCELLANEOUS

DATE	Aug 20 1959	Sept 29 1960	Sept 5 1963	Sept 30 1964	Nov 10 1964	Dec 20 1964	Jan 31 1965	Feb 28 1965	Mar 9 1966	Dec 13 1966	Mar 1 1967
Temperature °C											
Air			18.7	12.1	1.0	-29.0	-	18.0	4.0	2.0	-1.0
Surface	16.1	10.6	16.9	8.9	2.2	0.2	0.2	0.5	0.6	0.7	0.3
5 ft (1.5m)	15.5	10.5	16.8	8.8	2.3	2.8	2.2	2.0	1.7	2.4	1.8
10 ft (3.05m)	15.3	10.5	16.7	8.7	2.6	3.1	2.9	3.0	2.5	2.8	3.0
15 ft (4.6m)	14.8	10.4	13.9	8.7	2.8	3.2	3.0	3.2	2.6	3.1	3.0
20 ft (6.1m)	13.7	10.4	13.2	8.6	3.0	3.2	3.1	3.2	2.8	3.4	3.1
25 ft (9.1m)	12.0	10.4	11.9	8.6	3.2	3.2	3.2	3.3	3.2	3.4	3.3
30 ft (9.1m)	9.8	10.3	11.4	8.6	3.3	3.5	3.2	3.5	3.5	3.5	3.5
35 ft (10.7m)	9.5	10.0	10.3	7.5	3.7		3.6	4.2		4.3	4.2

APPENDIX VII

DISSOLVED OXYGEN CONCENTRATIONS - STATION I (1965)

DATE - 1965	May 19	June 5	June 7	June 9	June 14	June 18	June 21	July 5	July 10	July 12	July 16	July 24	July 26	July 30
Oxygen ml/1														
Surface	6.8	6.1	6.3	6.2	6.2	6.6	6.1	5.7	6.3	6.3	-	6.1	5.6	5.8
5 ft (1.5m)	6.7	5.9	6.3	6.0	6.1	6.4	5.8	5.8	6.3	6.3	-	5.6	5.4	5.8
10 ft (3.05m)	6.7	5.8	6.2	5.8	6.0	6.1	5.9	5.8	6.3	6.2	5.8	5.5	5.4	5.8
15 ft (4.6m)	6.6	5.7	6.0	5.7	5.8	5.8	5.7	5.6	6.1	5.8	5.4	5.3	4.7	5.6
20 ft (6.1m)	6.5	5.1	5.5	5.3	5.2	5.6	4.7	5.1	5.5	5.7	5.1	3.8	3.9	3.7
25 ft (7.6m)	6.4	4.8	5.3	4.6	4.4	5.1	4.5	4.7	4.5	4.9	4.3	3.3	3.1	3.0
30 ft (9.1m)	6.4	4.5	4.7	3.8	3.7	5.0	4.5	2.9	3.3	3.4	3.1	2.9	2.6	2.6
35 ft (10.7m)	6.2	4.1	-	3.1	-	4.7	3.4	2.6	2.7	2.5	2.1	2.3	1.9	1.7

APPENDIX VII (cont'd)

DISSOLVED OXYGEN CONCENTRATIONS - STATION I (1965)

DATE - 1965	Aug 2	Aug 6	Aug 9	Aug 13	Aug 16	Aug 18	Aug 27	Aug 30	Sept 3	Sept 11	Sept 13	Sept 27	Oct 9
Oxygen ml/1													
Surface	5.8	5.6	5.6	6.0	-	5.5	5.6	6.7	6.7	6.4	6.5	7.1	7.7
5 ft (1.5m)	5.7	5.5	5.5	5.9	-	5.4	5.8	6.3	6.6	6.2	6.5	7.3	7.7
10 ft (3.05m)	5.9	5.3	5.2	5.9	-	5.3	5.5	6.3	6.4	6.1	6.3	7.3	-
15 ft (4.6m)	4.6	4.6	4.1	4.8	-	4.5	4.9	6.2	5.8	6.1	6.1	7.4	7.7
20 ft (6.1m)	3.9	3.6	4.0	4.2	3.7	3.4	2.2	4.9	5.5	5.5	5.7	7.3	-
25 ft (7.6m)	3.0	2.7	2.9	3.0	2.9	2.7	1.9	2.3	4.5	2.7	5.1	7.3	7.7
30 ft (9.1m)	2.4	2.0	1.8	2.1	1.9	2.0	0.9	1.3	1.9	4.2	6.1	7.3	-
35 ft (10.7m)	1.6	1.1	0.9	1.5	1.2	1.3	0.6	0.7	1.1	6.0	6.2	7.3	7.8

APPENDIX VIII

DISSOLVED OXYGEN CONCENTRATIONS - STATION II (1965)

DATE - 1965	June 14	July 5	July 12	July 26	Aug 2	Aug 9	Aug 18	Aug 27	Aug 31	Sept 13	Sept 29
Oxygen ml/1											
Surface	6.0	6.3	6.7	5.9	5.7	5.6	5.7	5.6	6.2	5.9	7.3
5 ft (1.5m)	5.7	6.1	6.5	5.9	5.8	5.5	5.6	5.6	5.9	5.8	7.3
10 ft (3.05m)	5.7	6.2	6.6	5.5	6.4	5.3	5.6	5.7	5.8	6.1	7.3
15 ft (4.6m)	5.8	5.5	6.6	5.5	4.6	5.2	5.5	5.4	5.5	6.1	7.4
20 ft (6.1m)	5.8	5.1	6.5	3.5	3.4	2.5	4.2	3.9	5.3	6.7	8.0

APPENDIX IX

DISSOLVED OXYGEN CONCENTRATIONS - STATION III (1965)

DATE - 1965	June 14	June 21	July 5	July 12	July 26	Aug 2	Aug 9	Aug 18	Aug 27	Aug 31	Sept 29
Oxygen ml/1											
Surface	6.3	6.2	6.2	6.4	5.7	5.7	5.7	5.9	5.6	6.1	7.2
5 ft (1.5m)	6.1	6.2	6.0	6.3	5.7	5.6	5.5	5.8	5.6	6.0	7.1
10 ft (3.05m)	6.1	6.2	5.9	6.3	5.0	5.2	5.4	5.4	5.3	5.9	7.1
15 ft (4.6m)	5.9	6.0	5.7	6.1	4.2	4.8	4.2	4.3	4.4	5.6	7.0
20 ft (6.1m)	5.6	5.0	5.1	5.7	4.0	3.3	3.2	3.0	2.9	3.5	7.0
25 ft (7.6m)	4.9	4.2	4.7	4.9	3.6	2.9	2.8	2.3	2.1	1.6	7.1
30 ft (9.1m)	4.8	3.5	4.0	4.3	3.0	2.0	1.5	2.0	1.7	0.6	7.1
35 ft (10.7m)	3.9	3.0	3.4	3.0	2.5	1.3	0.9	1.4	0.9	0.4	7.3

APPENDIX X

DISSOLVED OXYGEN CONCENTRATIONS - STATION I (1966)

DATE - 1966	May 13	May 24	May 27	June 4	June 6	June 10	June 13	June 15	June 18	June 21	June 24	June 28	June 30
Oxygen ml/1													
Surface	6.0	6.9	5.8	5.9	6.4	6.1	6.7	6.3	6.3	5.8	6.5	6.1	6.4
5 ft (1.5m)	6.1	6.7	5.8	6.2	6.5	6.6	7.0	6.8	6.5	6.0	6.3	6.1	6.5
10 ft (3.05m)	6.1	6.7	5.5	6.2	6.5	6.6	7.0	6.5	6.8	5.9	6.9	6.0	6.3
15 ft (4.6m)	5.4	6.5	5.5	5.7	6.5	6.1	6.6	6.0	6.2	5.9	6.8	5.5	6.0
20 ft (6.1m)	5.3	5.9	5.4	5.4	6.2	5.9	6.6	6.0	5.8	5.7	6.1	5.5	5.4
25 ft (7.6m)	5.1	5.7	5.3	4.9	5.6	5.7	5.5	5.4	4.9	4.4	5.0	4.7	5.0
30 ft (9.1m)	4.3	5.7	5.3	4.8	4.8	4.9	4.2	4.9	4.6	4.2	3.5	3.9	4.2
35 ft (10.7m)	4.1	-	5.0	4.7	4.8	4.3	3.8	4.1	4.1	3.7	3.3	3.2	2.4

APPENDIX X (cont'd)

DISSOLVED OXYGEN CONCENTRATIONS - STATION I (1966)

DATE - 1966	July 2	July 4	July 12	July 15	July 20	July 22	July 25	July 28	July 31	Aug 2	Aug 5	Aug 9	Aug 12
Oxygen ml/1													
Surface	5.3	6.1	5.6	5.9	5.7	5.8	6.1	5.9	6.2	5.6	5.9	6.2	5.9
5 ft (1.5m)	6.5	5.7	5.8	6.2	6.7	6.4	6.1	5.6	6.6	5.6	6.4	6.2	6.0
10 ft (3.05m)	6.0	5.9	5.7	6.2	6.5	6.7	6.3	5.6	6.0	6.0	6.4	6.3	5.7
15 ft (4.6m)	5.9	5.9	5.8	6.4	6.3	5.8	5.9	5.6	5.8	5.4	6.2	5.3	5.5
20 ft (6.1m)	5.9	5.7	5.3	6.0	5.3	5.5	4.6	5.0	4.9	5.3	5.7	4.7	4.7
25 ft (7.6m)	4.8	5.6	4.5	4.7	4.1	3.5	4.1	4.1	3.7	4.2	3.8	4.3	3.4
30 ft (9.1m)	3.6	4.3	3.8	3.8	3.9	2.6	3.2	3.3	2.6	2.2	3.2	2.4	2.1
35 ft (10.7m)	3.3	2.6	3.8	2.6	2.3	1.9	1.2	2.1	1.9	1.6	2.5	2.0	1.7

APPENDIX X (cont'd)

DISSOLVED OXYGEN CONCENTRATIONS - STATION I (1966)

DATE - 1966	Aug 16	Aug 19	Aug 25	Aug 30	Sept 2	Sept 6	Sept 10	Sept 12	Sept 17	Sept 25	Sept 30	Oct 5
Oxygen ml/l												
Surface	6.4	8.7	5.9	5.7	5.9	5.6	5.6	5.6	5.7	5.5	5.6	5.9
5 ft (1.5m)	6.3	8.5	5.8	5.9	5.6	6.0	5.6	5.7	5.8	5.4	5.3	5.9
10 ft (3.05m)	5.9	7.3	5.8	5.7	5.6	5.6	5.7	5.8	5.7	5.4	5.2	5.7
15 ft (4.6m)	5.7	7.2	5.5	5.6	5.4	5.5	5.1	5.5	5.1	5.3	4.7	5.3
20 ft (6.1m)	5.3	5.7	4.3	4.1	4.7	4.7	4.2	4.1	3.8	4.7	4.7	5.3
25 ft (7.6m)	4.7	3.7	2.3	3.1	3.7	3.4	2.7	3.0	3.0	2.7	4.7	5.1
30 ft (9.1m)	2.1	2.1	1.1	1.0	1.4	1.8	1.9	1.8	1.5	2.4	4.7	5.1
35 ft (10.7m)	1.6	1.4	0.7	0.8	1.1	0.7	0.9	1.2	1.0	2.7	4.7	5.1

APPENDIX XI

DISSOLVED OXYGEN CONCENTRATIONS - MISCELLANEOUS

DATE	Aug 20 1959	Sept 29 1960	Sept 5 1963	Sept 30 1964	Nov 10 1964	Dec 20 1964	Jan 31 1965	Feb 28 1965	Mar 9 1966	Apr 6 1966	Dec 13 1966	Mar 1 1967
Oxygen ml/1												
Surface	8.0	6.7	6.3	7.2	7.8	7.8	7.2	6.3	7.1	7.0	7.4	5.9
5 ft (1.5m)	-	6.6	-	-	-	-	7.2	6.1	7.3	6.4	7.4	5.6
10 ft (3.05m)	7.7	6.6	6.0	7.2	-	7.5	6.6	5.8	6.7	6.4	7.2	5.3
15 ft (4.6m)	-	6.6	-	-	-	-	6.2	4.9	5.8	5.9	6.9	5.0
20 ft (6.1m)	7.0	6.6	2.7	7.2	-	7.7	5.3	4.4	6.5	5.0	6.1	6.2
25 ft (7.6m)	3.3	6.5	-	-	-	6.6	-	-	6.2	4.3	5.3	-
30 ft (9.1m)	1.3	6.5	1.1	6.9	7.5	-	4.6	3.9	6.2		-	3.4
35 ft (10.7m)		6.5		6.8	-	-	-	3.2			3.7	-

APPENDIX XII

OUTLET STREAM TEMPERATURES (deg C) 1965

Date	Max.	Min.	Mean	Date	Max.	Min.	Mean
July 24		15.3		Aug. 17	19.3	17.3	18.3
25	19.6	16.2	17.9	18	20.6	16.5	18.5
27	19.4	17.6	18.3	19	20.7	16.2	18.4
28	20.5	18.1	19.3	20	20.9	16.0	18.4
29	19.5	17.4	18.4	21	20.9	16.3	18.6
30	21.5	18.3	19.9	22	21.6	17.8	19.7
31	20.4	17.4	18.9	23	19.5	18.0	18.7
Aug. 1	22.6	19.4	21.1	24	18.6	17.4	17.9
2	23.2	19.4	21.3	25	18.0	17.2	17.6
3	22.4	19.2	20.8	26	18.0	16.8	17.4
4	20.2	18.7	19.4	27	18.8	15.3	17.0
5	19.9	17.9	18.9	28	15.8	14.3	15.0
6	21.8	18.2	20.0	29	15.7	14.1	14.9
7	21.8	18.0	19.9	30	16.1	15.0	15.5
8	20.7	17.9	19.3	31	16.9	13.7	15.3
9	21.0	18.0	19.5	Sept. 1	14.1	13.6	13.9
10	21.6	18.5	20.0	2	14.4	13.1	13.7
11	22.2	19.0	20.6	3	13.2	12.4	12.8
12	21.7	18.8	20.2	4	12.7	11.5	12.1
13	18.9	16.7	17.8	5	12.1		
14	18.8	16.2	17.5	20	6.7	6.2	6.4
15	20.3	16.8	18.6	21	6.0	6.0	6.4
16	18.1	16.9	17.5	22	6.3	5.6	5.9

APPENDIX XII (cont'd)

OUTLET STREAM TEMPERATURES (deg C) 1965

Date	Max.	Min.	Mean	Date	Max.	Min.	Mean
Sept. 23	7.4	5.7	6.5				
24	7.6	4.9	6.2				
25	5.1	4.3	4.7				
26	4.9	3.9	4.4				
27	5.9	4.0	4.9				
28	6.3	4.6	5.4				
29	6.2	4.8	5.5				
30	6.9	4.7	5.8				
Oct. 1	5.7	4.2	4.9				
2	5.6	4.1	4.8				
3	6.1	4.7	5.4				
4	5.2	4.4	4.8				
5	5.8	4.4	5.1				
6	5.2	3.8	4.5				
7	5.2	4.2	5.1				
8	5.7	4.6	5.1				
9	5.6	3.8	4.7				
10	5.2	3.4	4.3				
11	4.6	3.9	4.2				
12	4.4	4.1	4.2				
13	4.7	3.9	4.3				
14	4.7	3.3	4.0				

APPENDIX XIII

OUTLET STREAM TEMPERATURES (deg C) 1966

Date	Max.	Min.	Mean	Date	Max.	Min.	Mean
May 18	8.4			June 12	13.7	10.4	12.0
19	8.4	7.2	7.8	13	13.3	10.4	11.8
20	9.4	7.2	8.3	14	14.2	11.0	12.6
21	8.0	7.6	7.8	15	14.9	11.0	12.9
22	7.3	6.6	6.9	16	15.0	10.9	12.9
23	8.1	6.5	7.3	17	15.0	11.2	13.1
24	9.3	6.9	8.1	18	16.7	12.5	14.6
25	10.4	7.6	9.0	19	16.2	13.2	14.7
26	9.0	7.8	8.4	20	15.7	12.3	14.0
27	9.9	7.8	8.8	21	15.1	11.8	13.4
28	10.2	7.5	8.8	22	16.1	12.5	14.3
29	14.0	8.6	11.3	23	14.9	12.0	13.4
30	10.8	10.5	10.6	24	13.3	11.9	12.6
31	11.7	9.4	10.5	25	15.4	11.2	13.3
June 1	10.5	9.4	9.9	26	16.9	13.1	15.0
2	11.0	9.7	10.3	27	16.8	12.9	14.8
3	10.2	9.1	9.6	28	17.3	13.3	15.3
4	10.8	9.0	9.9	29	17.1	13.0	15.0
5	12.4	8.6	10.5	30	16.0	12.5	14.2
6	13.3	8.9	11.1	July 1	14.5	12.4	13.4
7	12.4	9.0	10.7	2	13.1	12.7	12.9
8	12.3	9.5	10.9	3	12.6	11.7	12.1
9	11.4	11.0	11.2	4	14.2	12.3	13.2
10	11.6	10.3	10.9	5	14.5	13.1	13.8
11	12.9	10.1	11.5	6	15.6	13.6	14.6

APPENDIX XIII (cont'd)

OUTLET STREAM TEMPERATURES (deg C) 1966

Date	Max.	Min.	Mean	Date	Max.	Min.	Mean
July 7	17.9	14.0	15.9	Aug 1	18.2	13.9	16.0
8	17.6	14.8	16.2	2	18.1	14.0	16.0
9	17.7	14.3	16.0	3	16.8	15.1	15.9
10	17.6	14.6	16.1	4	17.6	15.2	16.4
11	17.0	13.6	15.3	5	14.9	13.5	14.2
12	17.3	14.2	15.7	6	15.6	13.5	14.5
13	17.0	13.6	15.3	7	16.4	13.9	15.1
14	18.0	13.7	15.8	8	15.7	13.8	14.7
15	18.5	14.3	16.4	9	16.4	13.7	15.0
16	18.2	15.1	16.6	10	15.9	14.5	15.1
17	17.8	14.9	16.3	11	14.4	13.2	13.8
18	18.3	14.8	16.5	12	14.4	12.6	13.5
19	19.0	14.6	16.8	13	13.8	12.9	13.3
20	17.8	15.3	16.5	14	14.3	12.3	13.3
21	15.4	15.0	15.2	15	14.5	12.6	13.5
22	16.8	14.2	15.5	16	13.5	13.0	13.2
23	16.6	14.4	15.5	17	13.8	11.5	12.6
24	14.7	14.4	14.5	18	13.0	12.2	12.6
25	14.3	13.2	13.7	19	12.9	11.8	12.3
26	16.0	12.8	14.4	20	13.7	11.3	12.5
27	16.5	12.1	14.8	21	13.3	11.4	12.3
28	16.5	13.4	14.9	22	12.8	11.4	12.1
29	16.5	14.5	15.5	23	13.3	11.7	12.5
30	16.3	14.2	15.2	24	14.0	12.3	13.1
31	16.7	14.2	15.4	25	14.2	12.6	13.4

APPENDIX XIII (cont'd)

OUTLET STREAM TEMPERATURES (deg C) 1966

Date	Max.	Min.	Mean	Date	Max.	Min.	Mean
Aug. 26	13.8	13.3	13.5	Sept. 19	13.4	10.7	12.0
27	13.4	13.0	13.2	20	13.4	11.0	12.2
28	13.0	12.5	12.7	21	13.3	10.4	11.8
29	12.5	12.0	12.2	22	13.2	10.7	11.9
30	12.2	11.7	11.9	23	11.8	10.7	11.2
31	12.6	11.7	12.1	24	11.3	10.7	11.0
Sept. 1	12.7	11.8	12.2	25	10.6	10.1	10.4
2	12.3	12.0	12.1	26	11.6	9.8	10.7
3	12.6	11.5	12.0	27	11.0	10.0	10.5
4	12.8	11.6	12.2	28	11.5	10.5	11.0
5	13.4	11.8	12.6	29	10.3	9.5	9.9
6	13.1	12.5	12.8	30	10.6	9.4	10.0
7	12.9	12.5	12.7	Oct. 1	10.0	8.9	9.4
8	12.9	12.0	12.4	2	9.6	8.7	9.1
9	13.3	12.0	12.6	3	9.4	8.4	8.9
10	13.0	12.4	12.7	4	10.9	8.9	9.9
11	13.4	12.8	13.1	5	9.9	9.6	9.7
12	12.8	12.2	12.5	6	10.4	9.0	9.7
13	14.0	11.6	12.8	7	10.9	9.7	10.3
14	13.9	11.2	12.5	8	9.6	9.2	9.4
15	13.5	10.8	12.1	9	8.4	6.0	7.2
16	13.2	10.8	12.0	10	9.1	6.7	7.9
17	13.0	11.5	12.2	11	7.2	7.0	7.1
18	12.3	11.7	12.0	12		6.1	

APPENDIX XIV

SECCHI DISC READINGS (FEET) - SWAN LAKE 1965 - 1966

Date	Station I	Station II	Station III
5 July 1965	11.5	10.5	10.3
16 July 1965	8.0		
24 July 1965	11.0		
18 Aug 1965			15.5
23 Aug 1965	14.0	14.5	13.5
27 Sept 1965	11.5		
29 Sept 1965		11.5	11.5
9 Oct 1965	10.0		
18 May 1966	7.5		
24 May 1966	10.0		
27 May 1966			8.5
14 June 1966	14.25		14.0
20 June 1966	14.5	14.5	13.5
27 June 1966	21.0	21.0	22.0
4 July 1966	13.0	7.0	13.5
8 July 1966	14.5	14.5	12.0
13 July 1966	13.5	16.0	14.5
18 July 1966	17.5	16.5	17.0
1 Aug 1966	18.0	17.5	18.0
8 Aug 1966	15.5	15.5	15.0
15 Aug 1966	13.5	13.5	13.5
22 Aug 1966	14.0	16.0	13.0

APPENDIX XIV (cont'd)

SECCHI DISC READINGS (FEET) - SWAN LAKE 1965 - 1966

Date	Station I	Station II	Station III
3 Sept 1966	15.5	17.5	16.0
10 Sept 1966	14.5	15.0	15.2
17 Sept 1966	14.5	15.0	15.2
25 Sept 1966	13.7	13.2	13.8
30 Sept 1966	12.5	12.2	12.0
5 Oct 1966	12.8	13.2	10.5

APPENDIX XV

FLOW READINGS IN SWAN CREEK AND METHODS USED

Date	Method	Flow (cfs)
30 September 1964	Head Rod	23.9
27 June 1965	Head Rod	76.9
19 May 1966	Chip	27.6
23 June 1966	Chip	22.9
24 August 1966	Gurley	13.4
28 September 1966	Gurley	5.9

APPENDIX XVI

SPECIES OF PHYTOPLANKTON RECORDED IN SWAN LAKE

Chlorophyta

Closterium sp.

Planktosphaeria gelatinosa

Sphaerocystis schroeteri

Staurastrum gracile

Volvox tertius

Pyrrophyta

Ceratium hirundinella

Chrysophyta

Asterionella formosa

Dinobryon sertularia

Fragilaria crotonensis var. *prolongata*

Melosira italica

Navicula sp.

Stephanodiscus astraea

Synedra ulna

Tabellaria fenestrata

Cyanophyta

Anabaena circinalis

Anabaena macrospora var. *robusta*

Aphanizomenon flos-aquae

Aphanocapsa rivularis

Coelosphaerium Kuetzingianum

Microcystis aeruginosa

APPENDIX XVII

SPECIES PRESENT IN BOTTOM FAUNA - SWAN LAKE

Phylum Nematomorpha

Family Gordiidae

Gordius sp.

Phylum Nemata

Phylum Annelida

Class Oligochaeta

Family Aeolosomatidae

Aeolosoma sp.

Family Lumbriculidae

Lumbriculus inconstans

Family Tubificidae

Class Hirudinea - several species

Phylum Arthropoda

Sub-phylum Crustacea

Class Malacostraca

Order Amphipoda

Family Gammaridae

Gammarus lacustris

Family Talitridae

Hyalella azteca

Sub-phylum Insecta

Order Ephemeroptera

Family Leptophlebiidae

Leptophlebia sp.

Paraleptophlebia sp.

APPENDIX XVII (cont'd)

Family Baetidae

Callibaetis sp.

Neocloeon sp.

Cloeon sp.

Order Odonata

Sub-order Anisoptera

Family Aeshnidae

Aeshna eremita

Aeshna verticalis

Family Libellulidae

Cordulia sp.

Sub-order Zygoptera

Family Agrionidae

Ischnura sp.

Order Plecoptera

Family Nemouridae

Brachyptera sp.

Order Hemiptera

Family Corixidae

Arctocorisa sutilis

Cymatia americana

Cenocorixa dakotensis

Sigara decoratella

Order Coleoptera

Family Haliplidae

Haliplus sp.

APPENDIX XVII (cont'd)

Family Dytiscidae

Agabus sp.

Dytiscus sp.

Family Chrysomelidae

Donacia sp.

Order Trichoptera

Family Phryganeidae

Phryganea cinerea

Agrypnia straminea

Family Limnephilidae

Limnephilus sp.

Limnephilus infernalis

Order Diptera

Family Culicidae

Chaoborus sp.

Family Heleidae

One species

Family Chironomidae (several species)

Chironomus sp.

Pentaneura sp.

Family Tabanidae

One species

Phylum Mollusca

Class Gastropoda

Family Physidae

Physa sp.

APPENDIX XVII (cont'd)

Family Lynmaeidae

Lymnaea sp.

Family Planorbidae

Gyraulus sp.

Class Polocypoda

Family Sphaeriidae

Musculium sp.

Pisidium sp.

APPENDIX XVIII

DETAILS CONCERNING BOTTOM FAUNA SAMPLES USED IN DRY WEIGHT DETERMINATION

NO.	DATE	DEPTH (ft)	DRY WT.(gm)	SUBSTRATE
1	20 June 1966	2	0.53	Sandy, some vegetation and detritus.
2	27 June 1966	2	0.34	Brown mud, much detritus.
3	24 May 1966	4	0.14	Fine black mud, much detritus.
4	25 May 1966	4	0.79	Sandy, vegetated.
5	21 July 1966	4	0.29	Black mud, heavily vegetated.
6	16 June 1966	4.5	0.26	Fine grey mud, some vegetation. Much detritus.
7	29 July 1966	12	0.29	Brown mud, some vegetation and detritus.
8	16 Aug 1966	12	0.02	Clean, sandy.
9	8 June 1966	14	0.05	Grey mud, much detritus.
10	12 Aug 1966	18	0.11	Fine clean grey mud.
11	14 June 1966	21	0.23	Fine grey mud, little detritus.
12	28 May 1966	24	0.11	Fine clean black mud.
13	6 ? 1966	26	0.30	Fine grey mud.
14	16 July 1966	28	0.21	Fine clean black mud.
15	20 June 1966	31	0.11	Fine grey mud.
16	18 July 1966	34	0.17	Clean black mud.
17	14 July 1966	34	0.14	Fine clean black mud.
18	20 Aug 1966	34	0.11	Clean black mud.
19	17 Aug 1966	35	0.10	Clean black mud.
20	15 July 1966	36	0.13	Fine black clean mud.

APPENDIX XIX

MEAN WEIGHTS OF LAKE TROUT IN DIFFERENT LENGTH GROUPS

(Number of Specimens in Parentheses)

LENGTH CLASS (mm)	MEAN WEIGHT (gm)		
	Males	Females	Sexes combined
160 - 180	70 (1)	55 (1)	62 (2)
180 - 200	70 (1)	--	74 (1)
200 - 220	85 (1)	95 (1)	105 (24)
220 - 240	130 (2)	150 (2)	147 (25)
240 - 260	183 (2)	180 (1)	183 (12)
260 - 280	205 (2)	235 (1)	221 (5)
280 - 300	305 (2)	331 (3)	308 (10)
300 - 320	413 (6)	389 (5)	393 (15)
320 - 340	446 (10)	466 (10)	458 (25)
340 - 360	560 (15)	578 (15)	566 (30)
360 - 380	717 (9)	692 (9)	703 (22)
380 - 400	878 (5)	828 (5)	838 (13)
400 - 420	1,085 (6)	999 (11)	1,023 (21)
420 - 440	1,168 (4)	1,145 (9)	1,152 (13)
440 - 460	1,377 (6)	1,332 (4)	1,384 (13)
460 - 480	1,522 (7)	1,583 (4)	1,579 (13)
480 - 500	1,896 (3)	1,986 (2)	1,932 (5)
500 - 520	1,852 (4)	1,998 (2)	2,004 (7)
520 - 540	2,365 (3)	2,614 (2)	2,465 (5)
540 - 560	2,377 (3)	2,778 (1)	2,547 (5)
560 - 580	2,685 (1)	3,162 (2)	3,003 (3)
580 - 600	3,180 (5)	3,507 (2)	3,273 (7)
600 - 620	4,462 (2)	3,507 (3)	3,839 (6)
620 - 640	4,058 (3)	3,680 (1)	3,874 (7)
640 - 660	4,791 (5)	4,200 (1)	4,639 (8)
660 - 680	4,953 (3)	4,392 (2)	4,759 (6)
680 - 700	--	--	--
700 - 720	--	--	5,103 (1)